Benefits of musical training on implicit memory and learning in healthy older adults and individuals with dementia.

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By

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Declarations

The material being presented for examination is my own work and has not been submitted for an award of this or another HEI except in minor particulars which are explicitly noted in the body of the thesis. Where research pertaining to the thesis was undertaken collaboratively, the nature and extent of my individual contribution has been made explicit.

Signed:

Dated:

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Benefits of musical training on implicit memory and learning in older adults and individuals with dementia.

Lisa Thorpe

Abstract

Ageing is linked to a variety of health issues, but perhaps the most well documented feature of growing older is that it is associated with memory decline (Ward, Berry & Shanks, 2013). It is well established that explicit memory declines with age, with the rate of decline being an important predictor of the diagnosis of dementia (Ward et al., 2013). Implicit memory is involved in everyday tasks that, with practice, become largely automatic. The process of implicit learning is generally defined as the ability to acquire knowledge unconsciously. An effective way of improving health in older adults is through music .Making music is one of the essential skills that requires the use of implicit knowledge. Procedural learning is one type of implicit knowledge that focuses on the learning of a skill through repeated performance and practise. To become a professional musician takes years of skill training, for example, practising scales improves finger patterns in pianists, which over time becomes an implicit motor skill that helps with musical performance. Previous research that has looked at implicit memory in musicians, has focused on young adults and found that both musicians and non-musicians performed equally on implicit knowledge tasks (Bigand et al. 2001). This thesis aimed to look at whether musical training is associated with better performance in implicit memory in healthy older adults and individual with dementia. To do this implicit memory tasks including an adaptation of the Phoneme Monitoring Task (Bigand et al., 2001), Serial Reaction Time Task (Nissen & Bullemer, 1987) and The Word Completion tasks (Tulving, Schacter & Stark, 1982), were completed by healthy older adults and individuals with dementia both musicians and non-musicians.

Overall, results showed that musicians, both older adults and individuals with dementia, performed better than non-musicians on procedural learning tasks (Serial Reaction Time Task) but there was no difference on implicit tasks such as priming. Although both musicians and non-musicians with dementia showed reaction times that would suggest procedural learning for repeated sequences, only musicians showed a significant difference between repeated and novel sequences, suggesting that musical training benefits procedural learning. Overall, both health older adult musicians and musicians with dementia performed faster than non-musicians on both the Serial Reaction Time Task and the Adapted Phoneme Monitoring task. However, results did not reach significance on the Adapted Phoneme Monitoring Task. The results suggest that musical training benefits procedural learning in musicians, which could have positive implications for future learning in older adults and individuals with dementia.

Chapter 1

Introduction

The population of the UK is steadily increasing, with over 18% of the population made up of adults 65 years old and over (Office for National Statistics, 2019). This figure is set to increase to over 20% by 2038 (Office for National Statistics, 2019). Such an increase in the ageing population versus the working population is set to have an impact on society. Ageing is linked to a variety of health and psychological wellbeing issues. One of the most documented features of growing old is the association with memory decline. An effective way of improving health in older adults is through the use of music (Macdonald, Kreutz & Mitchell, 2012). Music performance in particular has a wide range of health benefits, for example, singing in choirs or being part of a wind ensemble can improve both breathing and mental wellbeing due to the increased self-confidence and performance techniques (Macdonald et al., 2012). One of the most documented benefits of music is its ability to help older adults remember past events. Music is highly connected to emotions, which in turn helps older adults to link particular music to those emotional memories (Macdonald et al., 2012). However, with life expectancy rising it has become more important to understand the processes associated with memory decline and the factors (such as music) that can help or hinder. Research in this area can help understand the underlying structure of memory and can have substantial and wider implications for future health research.

It is well established that explicit memory, the conscious recollection of previously learned information, declines with age, with the rate of decline being an important predictor of the diagnosis of dementia (Ward, Berry & Shanks, 2013). With over 850,000 adults in the UK currently living with dementia (Prince et al., 2014) there is an urgent need to fully understand how dementia affects our memory, both explicitly and implicitly, and the ways in which our everyday lifestyle can be helped or adapted to aid these changes. Alzheimer's Disease and Lewy Body Dementia (a form of dementia that shares symptoms with Alzheimer's Disease and Parkinson's Disease) form over 66% of the UK's population diagnosed with dementia (Prince et al., 2014). Therefore, it is important to look at both forms of dementia and understand how they affect our long-term memory and find ways in which we can support independent living in those with dementia.

One of the most researched forms of therapy for dementia patients, is currently the use of music. It is proposed that music can help manage emotions and behaviour as well as trigger memories for past life events (Nair et al., 2013). The rise in the interest of music for individuals with dementia is currently prominent in the media, including a recent BBC documentary about the use of singing in choirs to help aid cognition and mental wellbeing (Mohamed, 2019). Using music as a form of therapy is not a new concept. Music therapists have been using music performance to stimulate the brain for many years (Osman, Tischler & Schneider, 2014). The inclusion of individuals with dementia and their carers in music performance is a relatively established concept with Alzheimer's UK providing Singing For The Brain sessions. Research that has focused on the outcomes of these sessions has found an improvement in relationships, memory, and mood, as well as helping dementia patients accept and cope with the diagnosis of dementia (Osman et al., 2014).

Currently the majority of research using healthy older adults and individuals with dementia looks at how explicit memory is affected in later life (Jelicic, Craik & Moscovitch, 1996; Ward, Berry & Shanks, 2013). However, to fully understand long-term memory differences in the ageing population, it is important to research both explicit memory and implicit memory. Graf and Schacter (1985) stated that “Implicit memory is revealed when performance on a task is facilitated in the absence of conscious recollection” (Graf & Schacter, 1985, p. 501). These tasks are typically performed in a laboratory where participants show a greater amount of learning for previously studied stimuli than non-studied stimuli (Ward, 2018). Unlike explicit memory, implicit memory does not rely on the conscious retrieval of information. Therefore, it is possible that both implicit and explicit memory could work by using different memory systems within the brain. Understanding how implicit memory and learning is affected in those with different types of dementia could have an impact on their future living. For example, using procedural learning techniques such as repetitive movement or actions to learn how to complete daily tasks. These tasks could involve successfully buttoning a shirt, turning on a shower or moving between rooms in a house. Performing these everyday tasks could have a positive outcome for the individual with dementia, with possibility of retaining independent living for a longer period of time. These small benefits could also have an impact on the NHS, with individuals being able to live independently for longer would require less fulltime care from health services.

One of the most common forms of implicit memory is procedural memory. Procedural memory is responsible for knowing how to perform motor skills, for example, how to tie shoelaces or playing the piano (Simmons, 2011). A key element of forming a procedural memory is through practise of a specific motor skill. For a motor skill to become procedural, an individual must be able to perform that skill unconsciously without explicit recall. For example, musicians are found to have superior procedural memories due to the amount of practice of specific motor movements that occurs when playing an instrument (Simmons, 2011). Music performance requires the learning of scales, which is a skill that requires the learning of finger pattern. Over time, the finger patterns become an unconscious process and can then be applied to other music performances. A study by Hirono et al (1997), showed that individuals with Alzheimer's Disease successfully completed a procedural memory task (motor task) but could not complete declarative memory tasks. It was suggested by Hirono et al (1997) that the neural system used to complete procedural tasks is not related to the neural systems for declarative memory. If this is true, this thesis should see individuals with dementia performing as well as healthy older adults on procedural tasks. However, it is unclear the extent to which implicit memory declines with age or in those with dementia, and whether factors such as music performance or music training have a beneficial effect on implicit memory. By comparing musicians and non-musicians on tasks of implicit memory and learning, this thesis sets out to form an understanding of the difference in implicit memory between participants that have formal musical training and those who do not. If elderly musicians have preserved implicit memory in comparison to non-musicians, this might have implications for more everyday tasks which have an implicit or procedural element. As the focus of this thesis is implicit memory and learning, all tasks completed by participants will be experimental tasks.

1.1 Musical training

Music making is a multisensory activity that involves motor planning, preparation, and execution (Gooding et al., 2014). Instrumental training encompasses a variety of motor and auditory tasks, including the reading of musical notation, repetitive motor movements, multimodal sensory integration and decades of deliberate practice and music listening (Gooding et al., 2014). Musical expertise takes years of training, which typically begins at a young age and includes intensive repetitive practice (Hanna-Pladdy & Mackay, 2011). Musical training research has found cognitive advantages in verbal memory (Franklin et al., 2008), visuospatial awareness (Bidelman, Hutka & Moreno, 2013) and reading ability (Moreno et al., 2009) as well as plastic brain reorganisation in children (Loui et al., 2019). With older adults often experiencing declines in cognitive ability, including declines in explicit memory processes (Swaminathan & Schellenberg, 2018) it is important to investigate whether those cognitive advantages shown in young musicians continues throughout the life span.

One of the aims of this thesis is to look at the possible benefits of musical training on implicit memory and learning. This theme will be apparent throughout all studies. To do this, both musicians and non-musicians will complete all experimental tasks to enable a comparison to be made. In order to compare musicians and non-musicians, specific protocols were put in place to define musicians (see Chapter 4 for further details). These protocols continued throughout all studies enabling comparisons to be made across different studies and age brackets. Defining musicianship is very complex and has received considerable attention in music psychology literature. Many researchers have created a test that looks at the individual aspects that relate to musicality. These include: The Musical Ear Test (Wallentin, Nielsen, Friis-Olivarius, Vuust, & Vuust, 2010), the Profile of Music Perception Skills (Law & Zentner, 2012), the Goldsmiths Musical Sophistication Index (Mullensiefen, Gingras, Musil & Stewart, 2014), MUSE questionnaire (Chin & Rickard, 2012) and the MUSEBAQ (Chin, Coutinho, Scherer & Rickard, 2018). The Goldsmiths Musical Sophistication Index task (Mullensiefen et al., 2014) is a test of musicianship, that categorises experienced music listeners as musicians (Baker, Ventura, Calamia, Shanahan & Elliott, 2018). Including individuals that have never had an instrumental lesson can lead to theoretical issues and discrepancies in musical training research. Professional instrumental training has many cognitive differences compared to music listening; therefore, it would be difficult to categorise trained musicians and experienced music listeners in the same group (Baker et al., 2018). The Goldsmiths Musical Sophistication Index task (Mullensiefen et al., 2014) takes around 30 minutes to complete and includes a self-report questionnaire, a memory and perception tasks. Individuals with dementia would struggle to complete this task without help from a carer and with the possibility of task fatigue. As this thesis uses active performing musicians and non-musicians, with demographic groups including students, older adults, and individuals with dementia, it was important that musicians could be defined in the same way throughout all four studies. In order for the musical ability definition to be constant throughout, this research use participants who are active music performers, have participated in formal music lessons, and have musical theory knowledge (see Chapter 4 for an in-depth explanation).

1.2 Research questions

The purpose of the thesis is to build a body of knowledge that shows how musical training affects ageing with respect to implicit learning and memory. The current research aims to answer the following questions:

- Does musical training have an impact on implicit learning and memory?
- Does musical training prevent a decline in implicit memory and learning of older adults?
- Do adults with dementia show a decline in implicit memory and learning and does musical training convey a protective factor for those with dementia?

1.3 Structure of thesis

The current chapter has identified the research question, outlined the background and the current context of the research, and examined the rationale and aims for the study. The structure of the remainder of the thesis is as follows:

Chapter 2 The aim of this chapter is to provide background knowledge into implicit memory, procedural learning tasks, priming tasks and the effects of ageing on implicit and procedural memory.

Chapter 3 provides a background on implicit memory and music. This includes research that uses music tasks to look at implicit knowledge of music and the impact of musical training in older adults.

Chapter 4 focuses on developing the Phoneme Monitoring Task by Bigand et al. (2001) to create an implicit musical memory task to identify implicit memory differences between musicians and non-musicians. The Phoneme Monitoring Task was adapted to look at both implicit knowledge of musical structure and implicit memory for specific musical sequences.

Chapter 5 reports further developments of the Adapted Phoneme Monitoring Task presented in Chapter 4. This study focuses on the implicit learning and memory of repeated musical sequences of a larger number of presentations. By using musicians and non-musicians, this study was also able to look at whether musical training affects implicit learning on an implicit musical learning task.

Chapter 6 focuses on the possible benefits of prior musical training on implicit memory and learning in older adults, both musicians and non-musicians. In this study, participants were divided into three groups based on leisure activity: Musician, active non-musicians, and less active non-musicians. By comparing groups of non-musicians who have different activity levels, this study was able to analyse whether any advantages to implicit memory are specifically due to musical training or whether any advantages are simply due to an active lifestyle. In order to test for implicit memory and learning, three implicit memory tasks were completed by all participants: the Adapted Phoneme Monitoring Task developed in Chapter 5, the Serial Reaction Time Task and a Word Completion Task.

Chapter 7 focuses on the benefits of musical training on the implicit memory and learning of adults diagnosed with dementia. Participants were divided into musicians and non-musicians. All participants had a confirmed dementia diagnosis and were all in early stages of dementia. Participants completed three implicit memory tasks: Adapted Phoneme Monitoring Task, Serial Reaction Time Task, and a Word Completion Task.

Chapter 8 entails a concise summary of the findings of all four studies drawing on relevant literature and identifying key concepts throughout all studies. This chapter will also examine the implications of implicit memory research and how this can be developed for future research. The strengths and limitations of the studies are explored.

Chapter 2

Implicit memory

2.1 Long term memory: Explicit vs Implicit

The main role of long-term memory is to store and recall previous events or previously learned information (Cowan, 2018). This includes the ability to recognise people and places, as well as understand both words and numbers (Cowan, 2018).The concept of long-term memory is extremely fractionated, with many researchers showing that long-term memory can be divided into different sections. Some of the fractionations include the distinctions between explicit and implicit memory, and declarative memory and procedural memory. Tulving (1972) proposed one of the most influential distinctions between the different types of long-term memory. These included the differences in long-term memory processes between episodic and semantic memory (types of explicit memory) and procedural memory (a form of implicit memory). Cohen and Squire (1980) looked further at the differences between declarative knowledge and procedural knowledge in patients with amnesia on a mirror skills task. They found a distinction between declarative memory and procedural memory systems, as amnesic patients were able to retain "knowing how" (procedural knowledge) to do something rather than "knowing that" (declarative knowledge) they had completed a task. (Cohen & Squire, 1980).

Many studies have looked at the distinctions and connections between the different types of explicit and implicit memory. Some of these include: Semantic and episodic memory- the distinction between knowing (semantic memory) and remembering (episodic memory)(Squire & Zola, 1998); semantic knowledge and implicit knowledge- understanding the concept of knowing vs remembering (declarative vs procedural knowledge) and the connection between implicit and explicit memory systems (Tulving, Hayman & Macdonald, 1991); implicit and explicit memory- the relationship between different memory systems (Ward & Shanks, 2018); and the differences between implicit memory and procedural memory- the differences between motor skill learning and priming and whether these memory systems are different implicit processes. This thesis will focus on the different forms of implicit memory. More specifically, the distinction between implicit learning and procedural learning in older adults and individuals with dementia. This will be explored in Chapters 6 and 7.

Our understanding of the relationship between explicit memory and implicit memory has become more widely researched over the previous decades (Ward & Shanks, 2018). Explicit memory is described as “the conscious recollection of recently presented information or prior experiences” (Schacter, 1987, p. 501) and is measured by instructing participants to deliberately retrieve or remember information from previous experiences (Ward & Shanks, 2018). For example, participants are shown a list of words or pictures and later asked to recall as many as they can remember. Explicit memory is highly researched, and it is well documented that explicit memory declines with age (Ward & Shanks, 2018). Fleischman et al., (2004) conducted a longitudinal study over a period of four years looking at explicit memory of older adults. Participants with a mean age of 78.6 years completed a number of explicit tests including delayed recall, recognition of stories, number, and word tasks. They found that over a four-year period, older adult participants showed a progressive decline in all explicit tasks (Fleischman et al., 2004). Given the extensive research into explicit memory, there has been an increase in research into the understanding of implicit memory and the distinctions between explicit and implicit memory.

Implicit memory is acquired unconsciously. Graf and Schacter stated that “implicit memory is revealed when performance on a task is facilitated in the absence of conscious recollection” (Graf & Schacter, 1985, p.501). Unlike explicit memory, implicit memory is measured indirectly. For example, participants would view a set of pictures or words in the initial study phase of the task and later in the testing period, participants would be given a new task that appears to be separate to the original task but in fact will be related to the previous task. This new task could form a list of word fragments. Participants would be more likely to complete the fragments with the names of the pictures they have previously viewed than random words. Therefore, implicit memory is revealed by greater accuracy for previously studied items than new items (Ward & Shanks, 2018). This is known as priming and is a technique frequently used when testing for implicit learning.

Implicit learning is observed when participants show an improvement in response to the stimuli that have been previously presented, without any explicit training on those stimuli (Ward et al., 2013). Implicit learning tasks use a variety of priming techniques that act through automatic processes. Priming refers to the changes in processing shown by either speed, accuracy or bias to a stimulus that has been previously encountered (Gabrieli et al., 1999). The key element of all implicit learning tasks is that at no stage does the task refer to the prior experience or exposure to a stimulus at the time of retrieval. The testing of this memory usually takes the form of a delayed conditioning task, skill learning or repetition priming tasks (Gabrieli et al., 1999). This chapter will focus on different types of implicit learning tasks: Procedural tasks (Serial Reaction Time Task) and priming tasks (Word Completion Task and the Artificial Grammar Task).

2.2 Procedural learning tasks

Procedural memory is a type of implicit memory that is underpinned by the learning of habits or skills, specifically motor skills or cognitive skills that emerge in everyday life (Koch et al., 2020). Procedural memories are formed by the repeating of a skill, until that specific skill becomes an unconscious process (Koch et al., 2020). For example, learning to play music scales on the piano requires the learning of motor patterns from one key to another. In professional pianists this is an unconscious process due to the hours of practice that is entailed to become a professional musician. This thesis is interested in looking at implicit memory and learning and older age. The next section will focus on looking at procedural learning tasks.

2.2.1 Serial Reaction time task

Procedural memory is frequently studied by looking at the differences in motor skills on sequence learning tasks (Nissen & Bullemer, 1987). Sequence learning tasks are designed so that participants respond to a visual cue by pressing one of four keys that relates to the location of the cue on the screen (Nissen & Bullemer, 1987). The visual cues make up a sequence which is repeated throughout the task, unbeknown to the participant. For procedural learning to be apparent, participants would show a decrease in response time to the visual cue over the course of the task. If the sequence were to change, participants are expected to react slower to the visual cues as they are no longer using their procedural memory for the repeated sequence (Koch et al., 2020). The Serial Reaction Time Task (SRTT) is used frequently in research using participants of all ages and enables research to look at the effect of ageing on motor skills and implicit memory (Howard & Howard jr., 1989).

The term “implicit sequence learning” was introduced by Nissen and Bullemer (1987) by using the Serial Reaction Time Task (SRTT) to look at implicit learning of visual sequences. In the Serial Reaction Time Task, participants are asked to view a computer screen showing e.g. four spatial locations (normally represented by a shape), that correspond to four response keys (Example shown in figure 2.1). In each trial, a stimulus appears in one of the four spatial locations and the participant is asked to respond to the stimulus as quickly and accurately as possible. The stimuli followed a sequence; for example, the sequence BCDACDBACD represents a pattern where the stimulus appears in location B, followed by location C etc. (the letters represent the different spatial location). Typically, a block consists of several consecutive identical sequences. However, participants are not told this by the researcher. A block of randomised trials (i.e. not including a repeated sequence) is used in the first block and final block for researchers to demonstrate implicit sequence learning for repeated sequences. Learning is characterised as implicit when participants show improvements in reaction times throughout the repeated blocks of sequences, followed by slower reaction times in the final block of novel sequences (Nissen & Bullemer, 1987). Several studies have found implicit learning in the SRTT with participants reacting faster for stimuli occurring in a repeated pattern compared to stimuli located in random locations.

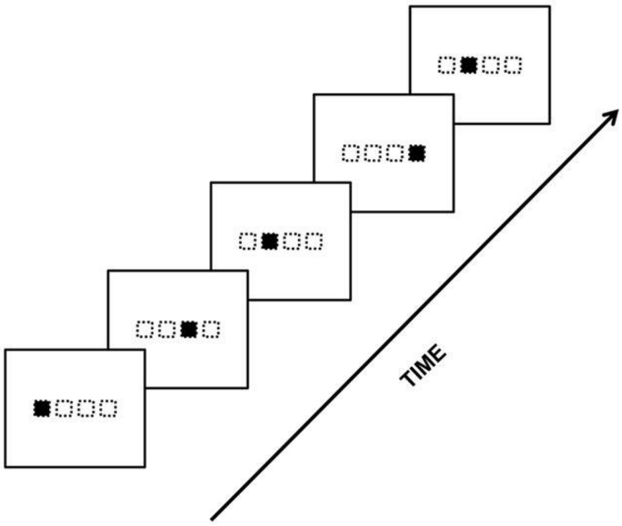

Figure 2.1. A depiction of the Serial Reaction Time Task (Nissen & Bullemer, 1987) by Daltrozzo and Conway (2014).

The SRTT has been used to investigate implicit learning in a number of neurodegenerative condition and acquired brain disorders. Nissen and Bullemer (1987) researched the performance of participants with amnesia on the Serial Reaction Time Task. They predicted that participants with amnesia would show impairments for sequence learning. In the task, participants completed four blocks of 100 trials consisting of ten repeated sequences (10 trials in a sequence), followed by four blocks of 100 trials of random stimuli. At the end of the final block, participants were asked explicitly if they had noticed a repeated sequence in the task at any point. Nissen and Bullemer found that compared to healthy adults, participants with amnesia were slower overall. However, the pattern shown in the reaction times across the blocks were similar for both groups. Both groups showed a reduction in reaction time for the repeating sequences and much slower reaction times for the random sequences, Therefore, patients with amnesia showed that they can implicitly learn sequences and make new associations without the explicit awareness of the repeating pattern, which matched the results for healthy older adults (Nissen & Bullemer, 1987). These results showed that despite the lack of explicit learning and even though adults with amnesia showed slower motor skills than control participants, individuals with amnesia were still able to show implicit learning for the visual sequence.

Howard and Howard Jr. (1989), used the SRTT to look at implicit sequence learning of older adults. The SRTT was completed by both younger and older adults for a comparison to be made between age. Further to the differences in age, the task also look at the comparison between sequence length (blocks of 100 stimuli or 160 stimuli). Participants were divided between each condition, with half of the older and younger adults completing the 100 stimuli block and the other half completing the 160 stimuli block. In the task, participants completed four blocks of repeated stimuli followed by a block of random stimuli. Howard and Howard Jr. (1989) found that older adults showed as much procedural learning for the repeated sequence as younger participants. Although reaction times for older adults were around 250m/s slower than their younger counterparts, the difference shown between reaction times of the penultimate block (the last block of repeated sequences) and the final block of novel sequences was around 200m/s for both age groups. As the SRTT is a motor task, it is expected that older adults show slower reaction times than younger adults due to the natural slowing of motor skills in old age (Ward & Shanks, 2018). This was also the case for the difference between longer and shorter sequence length. However, both groups showed less improvement in reaction times, with participants showing slower reaction times in blocks 3 and 4 for the 160 stimuli block than the 100 stimuli block. Despite the slower reaction times, both groups still showed slower reaction times for the final block with the difference between the penultimate block and the final block of sequences being less than 50m/s. This suggested that despite the difference in reaction times, older adults show equal amounts of procedural learning compared to younger adults (Howard & Howard Jr., 1989).

One important theoretical issue that occurs across research looking at older adults is the individual differences in ability, specifically verbal ability (Cherry & Stadler, 1995). Previous research by Craik, Byrd and Swanson (1987) found that older adults from lower socioeconomic and verbal circumstances were outperformed by younger adults and older adults with high ability on measures of verbal fluency and free and cued recall. Cherry and Stadler (1995) further looked at the differences in high and lower verbal ability in older adults on non-verbal tasks. Younger, low, and high verbal ability older adults took part in both the Serial Reaction Time Task and an explicit memory task. The aim of the task was to look at the differences in implicit learning in younger adults and older adults with different educational ability and their explicit awareness of the repeated sequences (Cherry & Stadler, 1995). It was suggested that if explicit knowledge contributes to implicit learning within the Serial Reaction Time Task, participants would show equal levels of performance for both implicit learning and explicit knowledge of repeated sequences (Cherry & Stadler, 1995). The SRTT comprised of 100 trials in each block (sequences of 10 trials repeated 10 times for the repeated sequences), with 6 implicit blocks in total. Results for the implicit task showed that younger adults and older highly educated adults gained equal amounts of implicit learning. As seen in

Howard and Howard Jr (1989), both groups of older adults showed slower reaction times than younger adults (Cherry & Stadler, 1995). In the explicit part of the task, participants were questioned to see whether they were aware of any repeated patterns. A generation task then followed. Participants saw 20 repetitions of a 10-trial sequence. As this is the explicit condition, participants were told to try and learn the sequence and predict the next location of the sequence (Cherry & Stadler, 1995). Results showed that some participants were aware that a sequence had occurred, but more participants had no explicit awareness for the repeated sequence (Cherry & Stadler, 1995). Group differences showed that older low educated adults did not perform as well as other groups, suggesting little to no explicit knowledge for the repeated sequences (Cherry & Stadler, 1995). Cherry & Stadler (1995) demonstrated the importance of taking individual differences into consideration when looking at older adult participants as there was no difference in age between younger adults and highly educated older adults, but less educated older adults showed less implicit learning and much slower reaction times.

Implicit sequence learning in those with neurodegenerative disease such as Parkinson's disease has attracted considerable attention. Parkinson's disease (PD) is a disorder of the nervous system and characterised by motor impairments (Smith, Siegert & McDowall, 2001; Gamble et al., 2014). The extent to which implicit sequence learning is impaired or intact in participants with PD is unclear with previous literature showing mixed results (Gamble et al., 2014). The first study by Ferraro, Balota and Connor (1993) saw patients with PD showing less implicit learning on the Serial Reaction Time Task than healthy individuals. This study was later replicated by Pascual-Leone et al. (1993) and again found that patients with

PD showed significantly less implicit learning than shown in healthy adults. As the Serial Reaction Time Task is a motor sequencing learning task, it is understandable that participants with PD would perform slower than healthy adults due to the motor deficit cause by the disease, therefore preventing PD patients from expressing the full degree of learning (Gamble et al., 2014).

Unlike the inconclusive results for patients with diagnosed Parkinson's disease, patients with cerebellar lesions show an inability to show implicit learning on a Serial Reaction Time Task (Gomez-Beldarrain, Gracia-Monco, Rubio & Pascual-Leone, 1998). The cerebellum is assumed to be predominantly used in motor learning tasks (Spencer & Ivry, 2009). Neuroimaging research has shown activity in the cerebellum during procedural memory tasks (Gomez-Beldarrain et al., 1998).

Spencer and Ivry (2009) modified the Serial Reaction Time Task to look at whether cerebellar patients would benefit on sequence learning tasks when the responses were directly cued. Two task conditions were used: direct cue condition and a symbolic cue condition. In the direct condition, the LED's under the response key were activated one at a time and participants had to press the illuminated key. In the symbolic condition, participants were instructed to look at a circle on a computer screen. The circle changes to one of four colours for each trial. Participants had to respond to the colour on the screen by pressing the corresponding button on their response pad. Spencer and Ivry found that when the task involved a transition between the stimulus on screen and response pad, participants did not show any implicit learning. However, when this transition was removed and the response pad directly cued participants, implicit learning was shown. This dissociation challenges previous research that suggests that the cerebellum is directly linked to sequence learning (Spencer & Ivry, 2009). Keele et al., (2003) conducted neuroimaging studies to look at the role of the cerebellum in sequence learning. They showed that the cerebellar did not increase in activity throughout the SRTT with increases in learning related activation observed in the motor cortex, the SMA and the inferior parietal lobe (Keele et al., 2003).

It is well known that individuals with dementia have explicit learning difficulties. However, results are inconclusive as to whether implicit learning is preserved in those with dementia (van Tilborg & Hulstijn, 2010). Knopman and Nissen (1987) were one of the first to look at the difference between older adults and individuals with specific types of dementia on implicit sequence learning task. Alzheimer's Disease the most common form of dementia, where no two patients show the same neuropathological changes (Knopman & Nissen, 1987). Due to the individual differences that are associated with different forms of dementia, it is unknown whether procedural learning is preserved or not. Knopman and Nissen (1987) used the SRTT, which comprised of five blocks of 100 trials (10 trials repeated 10 times in the repeated sequences block). Both the control participants (older adults) and the individuals with Alzheimer's Disease completed all five blocks. Results showed that both groups showed implicit learning for the repeated sequence with participants reacting slower for the random block of sequences in Block 5 than the repeated sequences in Block 4 (Knopman & Nissen, 1987). As expected, individuals with dementia reacted slower overall with reaction times around 500m/s slower than older adults. Despite this, it can be concluded that Alzheimer's participants showed procedural learning without having the ability to be explicitly aware of the repeated sequence. This supports the theory that implicit and explicit memory are part of a dual memory process. Individuals with dementia are unable to gain explicit memories but are able to gain procedural knowledge, suggesting that the neural circuits related to procedural learning are not damaged by dementia (Knopman & Nissen, 1987).

Unlike patients with Parkinson's Disease, individuals with Alzheimer's Disease have been shown to have the ability to implicitly learn and produce motor sequences (van Tilborg & Hulstijn, 2010). Van Tilborg and Hulstijn (2010) looked at the differences between individuals with Parkinson's Disease and those with Alzheimer's Disease. They hypothesised that participants with Alzheimer's would show procedural learning comparable to healthy older adults. However, participants with Parkinson's Disease would show less procedural learning than the other groups (van Tilborg & Hulstijn, 2010). Participants took part in the SRTT which contained six blocks overall. It was found that older adults and participants with dementia showed more procedural learning than participants with Parkinson's Disease, based on the increase in reaction times for the final novel block of trials compared the proceeding repeated block of trials (van Tilborg & Hulstijn, 2010). However, when van Tilborg and Hulstijn (2010) looked at the task error rates, individuals with Parkinson's Disease showed an increase in errors for the final block which indicated some implicit sequence learning. As Parkinson's patients are unable to react fast and therefore naturally make fewer mistakes, the increase in errors shows the difference between the repeated sequences and the random trials (van Tilborg & Hustlijn, 2010). Contrary to what was expected, participants with Alzheimer's Disease showed no increase in error rate between in the final block of sequences (van Tilborg & Hustlijn, 2010). However, they did find that error rate in participants with Alzheimer's increased in the fourth block of sequences. This suggests that the directional error rate cannot fully explain implicit learning in participants with Parkinson's Disease but does suggest that participants with Alzheimer's Disease have more difficulty with attention focus throughout a multi trial task (van Tilborg & Hustlijn, 2010).

2.3 Priming tasks

2.3.1 Word completion task

Word completion tasks are a simple and popular way of showcasing implicit learning using a non-motor task (Greenwald & Banaji, 2017). In a word completion task, in the initial study phase of the task participants are unconsciously exposed to multiple words (*GRAPE, MUTTER*). After a period of time, participants are asked to complete a word fragment, for example *GR* _ _ _ or *MU* _ _ _ *R*. An implicit memory effect is apparent if the completion of GRAPE or MUTTER (as opposed to GROUP or MURDER) is greater for those who saw GRAPE or MUTTER in the study phase of the task than those that did not (Greenwald & Banaji, 2017).

It is well recognised that healthy adults show priming for words by completing more fragments with words that have been previously studied than those that have not (Gabrieli et al., 1999). Tulving, Schacter and Stark's (1982) study was one of the first to look at the priming effect of words over a longer period of time. Previous studies that have completed the same word completion task have, on average, started the testing phase of the task after one hour of completing the study phase of the task. Tulving and colleagues looked at the retention of the priming effects found in previous studies by completing the testing phase of the task after one hour and then again after seven days. It was found that participants still showed implicit knowledge of previously seen words after seven days, with little change in the reduction of the priming effect from one hour to seven days (Tulving, et al., 1982). To check for explicit remembering of the previously seen words, participants also completed a recognition task, where they answered yes or no to whether they recognised the word. Participants recognition for the previously seen words showed a large reduction in words they had remember after 7 days (Tulving et al., 1982). Graf and Mandler (1984) suggested that the long-lasting priming effect was due to the deliberate retrieval of the word, as when participants do not complete the word immediately they may attempt to retrieve the information from words they have previously seen suggesting the use of explicit memory for the retrieval of words. This suggestion questioned the validity of the word completion task as a test of implicit memory. However, if this was case, studies looking at the longevity effects of priming on word completion task in patients diagnosed with amnesia would find that no priming would occur at any time period (Roediger, Weldon, Stadler & Riegler, 1992). Tulving, Hayman and Macdonald (1991) contradicted this theory by showing a strong effect of priming durability, with densely amnesic patients showing priming for words after a four-week period of time. This would suggest that word completion task is a test of implicit memory rather than explicit memory.

Amnesia is a memory deficit caused by brain damage or disease that stops an individual from forming new memories (Allen, 2018). Patients with amnesia lose their explicit memory but retain, it is suggested, their implicit or procedural memory. For example, trained pianists that develop amnesia are still able to play the piano (procedural memory) but would not be able to describe their most recent recital. Due to this memory deficit, if the word completion task did use explicit retrieval to complete previously seen words, participants with amnesia would not show any priming effects due to their lack of explicit retrieval (Roediger, Weldon, Stadler & Riegler, 1992). Tulving, Hayman and Macdonald (1991) showed a strong effect of priming on a word completion task when looking at an individual case study, K.C. When compared to healthy participants, K.C.'s level of priming was better, and his priming persisted for several month after testing, thus, suggesting that word completion tasks are tests of implicit learning (Tulving et al., 1991).

Priming tasks, such as Word Completion task, are popular implicit memory tasks specifically used in ageing research (Fleischman et al., 2004). Understanding whether priming deteriorates in older adults can be best shown in longitudinal studies. Hultchs et al., (1992), Christensen, Henderson, Griffiths and Levings (1997) and Davis, Trussell and Klebe (2001) all conducted longitudinal studies that looked at the effect of priming in older adults. All studies used the Word Stem Completion Task over a time period of 3 -10 years and all found that there was no age-related decline in the priming tasks. Fleischman et al., (2004) further developed the previous longitudinal studies by looking at the possible age-related differences on several word completion and picture naming tasks. 140 participants were tested over a 4-year period completing four implicit tasks: Word Identification Task, Word Stem Completion Task, Category-exemplar Production Task, and the Picture naming task. Compared to previous longitudinal studies, Fleischman et al., (2004) required participants to complete each task every year over the period of 4 years. Previous studies had only collected data for the Word Stem Completion task at two different periods of time, meaning that the study by Fleischman et al., (2004) was done with a longer time period in-between testing phases and more data comparisons. All participants first completed a study phase for the word tasks and the picture task. The study phase for the word tasks was the same for all three word associated tasks. Participants were required to read a word from a computer screen as accurately as possible. Participants thought that they were being scored on how accurately they could read the word (Fleischman et al., 2004). In the study phase for the picture task, participants were again asked to either read the word that appeared on the screen or the name of the picture that appeared on the screen. Participants then competed the four implicit tasks. In the Category-exemplar task, participants were given a category, for example Vegetable, and asked to name as many items that belong to the category as possible. It was expected that participants would name more items that had been previously studied than those that had not. In the Word Stem Completion task, a word stem appeared on a computer screen and participants were given 10 seconds to complete the word stem. Half of the stems were formed of words that had been previously studied and the other half were unstudied words. Again, it was expected that participants would complete stems faster and more accurately when they contained words that had been previously studied. In the Word Identification task, Participants were told they were being tested on how well they could visually identify a word. A word would appear on a computer screen for a short amount of time. After each appearance, the length of time would increase gradually. Participants were encouraged to respond to the word they though was being displayed on screen even if they thought it was incorrect. As in the word stem task, it was expected that participants would recognise words faster if they had previously seen them compared to novel words. Finally, the Picture Identification task, followed the same procedures as in the study phase. Participants were asked to read the word or name of the picture as quickly and accurately as possible. It was expected that participants would respond faster to those items that had been previously viewed in the study phase. All participants also completed an explicit memory test after each implicit task.

Fleischman et al., (2004) found that explicit memory declined with age over the four years in all tasks. This was not the case for the implicit memory tasks. Priming results remained constant for all implicit priming tasks, with no differences found between the word and picture tasks. The difference between explicit memory and priming results shows that although explicit memory declines with age, implicit memory remains stable (Fleischman et al., 2004). These results have possible implications for early detection of Alzheimer's Disease. It has been suggested that some forms of priming are reduced in those with Alzheimer's Disease. Therefore, low scores on explicit memory tasks, coupled with low scores on priming tasks could give an early indication the neuropathology is present and that a clinical diagnosis of Alzheimer's disease is necessary (Fleischman et al., 2004).

If priming is preserved in those with Alzheimer's Disease, it would be expected that individuals diagnosed with Alzheimer's disease would perform as well as healthy older adults and younger adults on priming tasks such as the Word Stem Completion Task. McGeorge, Taylor, Sala and Shanks (2002) looked at the differences between healthy younger and older adults compared to individuals diagnosed with Alzheimer’s disease on the Word Stem Completion Task. In the study phase of the task, participants were presented with words either visually on a computer screen or orally. By doing this McGeorge et al. (2002) were able to look at the contribution of conceptual processing on the Word Stem Completion Task. After completing the study phase, all participants took part the in the visual word stem task. Word stems appeared on a computer screen and participants were asked to complete the word as quickly and accurately as possible. Results showed that participants who completed both visual tasks (visual study/visual test) showed priming effects for words that had been previously viewed compared to participants that completed the oral study and visual stem completion. All participants showing no priming effects for the oral to visual task (McGeorge et al., 2002). Individuals with Alzheimer’s Disease showed impaired priming compared to control participants and this impairment occurs in both priming conditions. This difference in implicit memory could not be due to differences in conceptual processing between groups as all participants showed no priming effect for the oral to visual priming task and both healthy older and younger adults showed priming for previously seen words in the visual priming task (McGeorge et al., 2002). This suggests that priming is preserved in healthy older adults and declines in individuals diagnosed with Alzheimer’s Disease.

2.3.2 Artificial Grammar Learning Task

Human language learning relies on the ability to learn grammatical rules that consist of number of vocal sounds and phonemes combining to communicate a meaning (Silva, Inacio, Folia & Petersson, 2017). Human speech is not explicitly taught and is learned through implicit exposure. Therefore, implicit memory plays an important role in acquiring the learning of grammar, or the rules of language (Ettinger, Margulis & Wong, 2011). Many studies that have looked at implicit language learning have demonstrated the importance of linguistic structure in the recognition of words (Ettlinger, et al., 2011). Saffran, Aslin and Newport (1996a) found that infants can discriminate words from non-words (combination of random syllables) on a word segmentation task.

The Artificial Grammar Learning Task (AGLT) is used to assess a participant's ability to learn language sequences which are generated by a finite state language (Schiff, Sasson, Star & Kahta, 2017). The finite state language is "a finite or infinite set of strings (sentences) of symbols (words) generated by a finite set of rules (grammars), where each rule specifies the state of the system…after the rule is applied" (Chomsky & Miller, 1958, p92). Reber (1967) was one of the first to develop the AGLT to test implicit learning in adults. Participants were asked to memorise a sequence of previously generated letters. The letter sequences range from two to nine letters long. Participants are not told that the sequences are based on specific grammar and are simply asked to memorise them. In the testing phase, participants were told that the letter strings were based on specific rules and were instructed to categorise new letter strings into "grammatical" or "randomly constructed" sequences. In order for a string to be "grammatical" it must follow the grammar presented in figure 2.2. For example, the string TPTXXVS would be "grammatical" as it follows the direct of the arrows. However, VXXS would be "randomly constructed" as it does not follow the arrow direction.

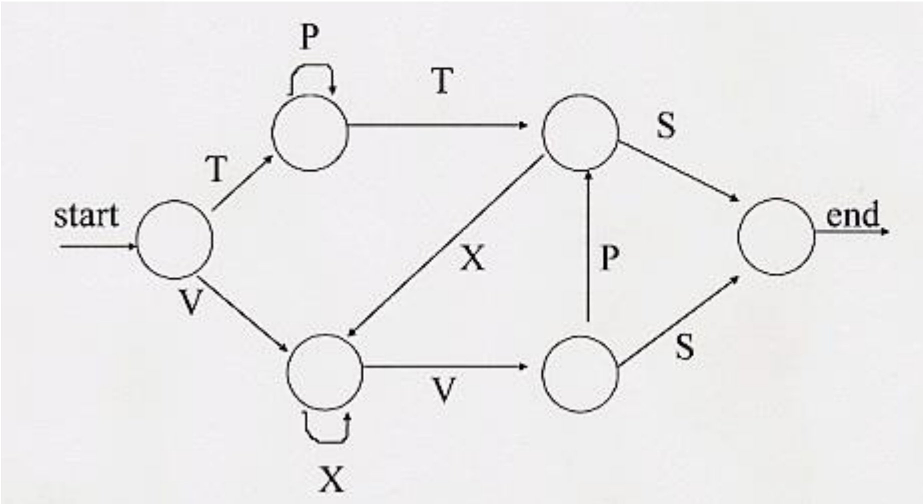

Figure 2.2 -An example of a grammar rule used in the Artificial Grammar Task (Reber, 1967)

Reber (1967) found that participants performed above chance when distinguishing grammatical sequences from randomly constructed sequences but were unable to verbalise the strategies used or point of the rule used when performing the task. This implies that implicit learning was completed without any intentional learning strategies (Reber, 1967). Many studies have replicated this finding, including those focusing on participants with amnesia (Knowlton, Ramus & Squire, 1992).

As previously discussed, patients with amnesia are severely impaired on explicit memory tasks but are fully intact on many other implicit learning tasks (Knowlton et al., 1992). Knowlton et al., (1992) used the AGLT to look at implicit language learning in participants with amnesia. Results showed that amnesic patients were as able as control participants to classify letter sequences that followed the grammatical rule without explicit recognition (Knowlton et al., 1992). It is suggested that for learning tasks based on rules, implicit and explicit memory are two separate memory systems. One system storing the explicit information that is provided to the participant and the second for implicit associations between the features of the stimulus or abstract information about the stimuli (Knowlton et al., 1992).

Research looking at artificial grammar learning in patients with neurological disorders further strengthens the argument suggesting that implicit and explicit memory rely on separate memory systems. Participants diagnosed with Parkinson's disease are shown to have intact implicit memory but impaired explicit memory (Reber & Squire, 1999). Reber & Squire (1999) found that patients with PD performed above chance on the traditional artificial grammar task, suggesting an intact implicit learning for language. This shows that acquiring abstract information about a complex rule system does not rely on explicit learning (Reber & Squire, 1999).

Many studies have used the structure of the artificial grammar task to look at the visual and auditory domains. van Witteloostuijn, Boersma, Wijnen and Rispens (2017) looked at performance on a visual artificial grammar learning task between individuals with and without dyslexia. Dyslexia is a disorder that hinders learning to read and spell, despite the absence of neurological impairments (van Witteloostuijn et al., 2017). A general hypothesis is that the difficulties in reading and writing occur due to deficits in phonological awareness (van Witteloostuijn et al., 2017). Phonological awareness is related to the ability connect letters to sounds which affects the ability to spell (van Witteloostuijn et al., 2017). Visual artificial grammar learning follows the same principle as the artificial grammar task. However, the sequences generated are pictures of shapes rather than letters. van Witteloostuijn et al., 2017 showed that individuals with dyslexia performed worse than non-dyslexic individuals on the visual task. However, when comparing different ages, they found that adults perform better than children. This suggests that adults with dyslexia learn to use other cognitive processes such as visual processing, pattern recognition or possibly explicit memory to enhance task performance (van Witteloostuijn et al., 2017).

As discussed, language is primarily learned through human interaction and communication which, in turn involves a range of cognitive processes in perception and processing (Rohrmeier & Rebuschat, 2012). These processes have shown similarities when compared to music learning. Music knowledge, like language, is implicit and is made up of complex grammar rules (Rohrmeier & Rebuschat, 2012). Therefore, it would be expected that musicians would perform better than non-musicians on language tasks, specifically the artificial grammar task, because of the similarities in cognitive processing of rules.

Bigand, Perruchet and Boyer (1998) formed an artificial grammar task based on sequences of timbre to look at how artificial grammars of timbre are learned. Timbre can be defined as the distinct difference in the sound produced by different instruments (McLachlan, 2016). For example, if a flute and a piano were to play the same note, the instrument would be identifiable because of the different sound it produces (different timbres). The timbre task developed the Reber (1967) artificial grammar task, as each letter was represented by a different timbre sound, for example a trumpet followed by piano followed by a violin. Participants were split into implicit and explicit memory conditions. In the implicit condition, participants were told to memorise the timbres and state whether they had heard the sequence before. In the explicit condition, participants were told to memorise the sequences that had been produced following a set of rules. They were told that trying to figure out the rule would help with memorising the sequences. Bigand, et al. (1998) found that participants performed better in the implicit memory condition showing that the use of timbre to represent a letter is internalised after simple exposure without the need for explicit analysis processes. Participants were unable to provide any explicit evidence about the timbre sequences they had heard and therefore information acquired in the learning phase of the task is implicit in nature and participants would have difficulty in intentionally accessing this information in order to judge the grammaticality of the new sequences (Bigand et al., 1998).

This thesis will use both procedural and priming tasks to understand how musical training can benefit implicit learning in older adults and individuals with dementia (see Chapters 6 and 7). Although the artificial grammar task has been frequently used in other studies as a priming task, this thesis will focus on the Serial Reaction Time Task, the Word Completion Task and an implicit musical task. The artificial grammar task will not be used due to the population in which this thesis is focused on. The grammar task takes a long time to complete and is quite a complex task. Due to focusing on older adults and more specifically individuals with dementia, it is important that tasks are easy to understand, simple to complete, and will not cause unnecessary task fatigued.

Human memory can arguably be described as multi memory system (Gabrieli et al., 1995). The dissociation between implicit and explicit memory can be demonstrated through the damage shown in explicit memory in patients with amnesia and neurological disorders but an intact implicit memory (Gabrieli et al., 1995). Instances of damage to only one memory system helps to show that the long-term memory systems work independently of one another and damage to either form of memory could still leave the other intact (Gabrieli et al., 1995).

The following chapter will concentrate on a further understanding of the effect of music-making and musical training on implicit and explicit memory in both younger and older adults. As discussed previously, music learning shares similar characteristics to language learning, however, musical training and instrument learning involves the use of additional complex cognitive processes such as sensory and motor skills (Anaya, Pisoni & Kronenberger, 2017). In order to understand the role music may play in implicit and explicit memory process, the following chapter will explore implicit musical memory tasks and look at whether the complex cognitive skills needed to be a musician benefits implicit processes and could possibly provide further evidence for independent implicit and explicit memory systems.

Chapter 3

Implicit knowledge, memory, and music

Music has a prominent role in everyday life for many people. Globally, music is enjoyed within all human cultures (Ettlinger et al., 2011). Hearing music, both pleasant and unpleasant, has been shown to activate the entire limbic system (Blood & Zatorre, 2001) and as this is involved in processing emotions and controlling memories, it is not surprising that music evokes strong emotions and memories (Jancke, 2008). Musical expertise has been found to be associated with aspects of cognitive processing, with research showing that children and adults who have undertaken musical training have better working memory than non-musicians on verbal and digit span tasks (Lee, Lu & Ko, 2007). Sluming et al. (2007) found that there is more grey matter in the frontal cortex of musicians, compared with non-musicians, which is known to accommodate the neural networks involved in working memory processes. This showed that taking part in musical training, in particular learning to read music, alters the brains circuit organisation which benefitted performance on non-musical visuospatial task (Sluming et al., 2007). Improvements in the visuospatial network suggests that musicians show better recall and verbal techniques than non-musicians (Slumming et al., 2007).

As discussed in Chapter 1, the mastering of a musical instrument requires years of formal training which includes the ability to read musical notation; understand musical theory; listen, process, and respond emotionally to music (Ettlinger et al., 2011). These advanced skills have been shown to enhance visual, auditory, and motor processing in musicians (Bangert et al., 2006). There is a widespread view that learning to play a musical instrument in childhood results in an increase speed and accuracy for fine motor skills throughout the lifespan (Hyde et al., 2009). It is likely that auditory and motor networks are strongly linked in the musician's brain. Conde, Altenmuller, Villringer and Ragert (2012), used the SRTT (discussed in Chapter 2) to look at auditory and motor performance in musicians. In order to test for performance on auditory tasks, Conde and colleagues used added an auditory feedback to the SRTT, so that when participants pressed the allocated key, a piano note sounded. Results showed that musicians reacted faster for the auditory sequence (even though the sound was produced 200ms after the participants had pressed the allocated key) than the normal SRTT condition. Although participants in the auditory condition were not asked to remember the tone sequence, this cannot be ruled out as an explanation. However, due to years of professional training it is possible that the auditory feedback helps with the timing of the tempo and rhythm of the sequences and therefore allows musicians to prepare for which key to press leading to faster reaction times (Conde et al., 2012).

Musical competence often takes years of intensive training. Over the years of training, musicians learn specific perceptual skills for example, ear/listening training, music analysis and explicit knowledge about western music structure, as well as developing motor skills when learning to play an instrument (Bigand & Poulin-Charronnat, 2006). All of these skills influence the way a musician interprets and processes musical stimuli. With the extensive training, it is not surprising that musicians differ from non-musicians on musical tasks (Bigand & Poulin- Charronnat, 2006). However, when focusing on implicit tasks, differences between non-musicians and musicians are not as expected. Bigand and Poulin-Charronnat (2006) describe non-musicians with extensive exposure to music as "experienced listeners". Non-musicians with high levels of listening experience have shown similar results to trained musicians on priming tasks (Bigand & Poulin-Charronnat, 2006). A study by Bigand & Poulin-Charronnat (2006) showed that non-musicians were able to perceive musical tensions and relaxations in both melodies and harmonic sequences as well as musicians on music priming tasks. Researchers have argued that musical abilities develop implicitly up to the age of 10 due to the incidental exposure to music. However, these skills do not evolve without explicit training (Bigand & Poulin-Charronnat, 2006). When using explicit tasks that require the use of musical knowledge, researchers have found a difference in musical ability between musicians and non-musicians (Bigand & Poulin-Charronnat, 2006). This finding is not surprising. Technical musical terms will be unfamiliar to non-musicians which biases the task towards musicians. Using implicit tasks to look at music competence has found that non-musicians are not able to technically describe what they are listening to, but they are able to unconsciously process what they are hearing (Bigand & Poulin-Charronnat, 2006). These findings can be seen in mere exposure tasks that highlights a greater liking for previously heard music than novel music in both musicians and non-musicians.

3.1 Mere exposure

Training to become a professional musician takes years of disciplined practice. However, being able to listen, process and respond emotionally to music is shared across both musicians and non-musicians and depends on implicit exposure to music. This has been shown in multiple studies that have looked at the mere exposure effect for music (Halpern & Mullensiefen, 2008). The mere exposure effect can be described as the increased liking for an unfamiliar item if it has been previously encountered regardless of conscious recollection (Peretz, Gaudreau & Bonnel, 1998). The mere exposure effect for musical stimuli has been found in both young adults (Peretz et al., 1998; Schellenberg, Peretz & Vieillard, 2008) and healthy older adults (Halpern and O'Connor, 2000).

Peretz et al. (1998) was one of the first to establish the implicit nature of the mere exposure effect in the musical domain. The experiment was designed so that in the initial study phase all participants would incidentally encode the tunes that were presented to them. Both implicit and explicit memory was tested on all participants through an affect and recognition task. In their first experiment, participants were exposed to 40 melodies from popular repertoire (20 familiar tunes rated highly on familiarity and 20 unfamiliar tunes rated low on familiarity ratings) and decided whether each extract was familiar or unfamiliar to them. In the task phase participants listened to 80 melodic extracts. Participants were told that the second phase of the study was an inquiry about musical taste that would be used for a future study. Half of the participants took part in the implicit memory condition. Unbeknown to the participants the extracts they heard were the same as the extracts heard in the study phase of the task and they were asked to rate their liking for each extract on a scale of 1 to 10. The second group completed the explicit memory condition where they were asked if they had heard each music extract in the prior section. Around two to four months later some participants were retested to look at the retention of melodies after several months. Results showed that mere exposure effect was present for music liking after a single repetition (second time of hearing) of the melody. A single repetition was enough to show an increase in liking for unfamiliar melodies both at the initial testing phase and in the retest. Peretz et al. (1998) also found that participants rated the familiar melodies higher in terms of liking than the unfamiliar melodies of the same musical genre. This showed that there was preference bias to what participants already knew. Experiment 2 looked at the longevity effects found in Experiment 1. They followed the same procedure; however, four extra participant groups were added to test the difference in multiple different time delays that differed from the delays used in experiment 1. These time delays consisted of five minutes (as the first experiment), 24 hours and 40 days between the study and test phase of the task. Results provided further evidence for a lack of association between implicit and explicit memory. After one-month, implicit memory for the familiar melodies had disappeared. However, participants were still able to distinguish between previously heard melodies in the explicit memory condition (Peretz et al., 1998).

Further studies have looked at the effect of changes in pitch and tempo for unfamiliar melodies on memory performance. Schellenberg, Stalinski and Marks (2014), state that a melody's identity is determined by the duration of the tones used to make a melody. Surface features such as pitch, tempo and timbre are irrelevant for identifying a melody. We all have the ability to imagine *'Happy Birthday'* played on either a slow, low pitched instrument or quickly on a high pitch instrument (Schellenberg et al. 2014). However, it is the relations between the notes and duration that makes the tune identifiable. This is further shown in Western music when a composer gives a tempo range, for example presto or andante, rather than a specific tempo indicator and the piece is still identifiable despite the performer's interpretation. Halpern and Mullensiefen (2008) looked at the influence of an encoding task and tempo changes to implicit and explicit memory for short melodies. The tempo of melodies was either reduced or increased by 15-20%. For the encoding study phase of the task, participants were asked to either identify the instrument the melody was played on or to rate how familiar the melody was. In the testing phase, participants were asked to either identify the "pleasantness" of the melody (implicit memory condition) or state whether they had previously heard the melody in the study phase of the task (explicit memory condition). Unlike changes in timbre, results showed that changes to the tempo affected implicit memory results, with participants rating the pleasantness lower for melodies that had changed in tempo, compared to those that had stayed the same. Changes to both the timbre and tempo impeded explicit memory for previously heard melodies. One explanation for the differences shown in tempo changes for implicit memory could be the importance of timbre and tempo to a melody. A melody of a song or instrumental music is able to be aurally replicated despite any conscious awareness of the original instrumentation and is still recognised as the same melody (Halpern and Mullensiefen, 2008). However, tempo is an integral part of synchronising multiple music parts and a key part in reproduction of music therefore causing recognition problems (Halpern and Mullensiefen, 2008).

Differences in memory processes were further investigated by Schellenberg et al., (2014) where they looked at whether participants can remember the key and tempo of unfamiliar melodies. It was predicted that if participants are able to remember the original melodic features heard in the study phase, recognition of the melody should be impaired when the key and tempo differ from the one heard at study phase (Schellenberg et al., 2014). In order for this task to be effective, participants first had to establish what changes in key and tempo sounded like, therefore a well-known tune, *Happy Birthday* was played in multiple different keys and tempos to demonstrate that the changes in key and tempo had no effect on the melody of the tune. Schellenberg et al., (2014) focused only on explicit memory. In the study phase of the task, participants were asked to judge how happy or sad an unfamiliar melody sounded. Half of the unfamiliar melodies heard in the study phase then changed in either key or tempo. At testing phase participants were asked to identify whether they had heard each melody before. Results showed that changes in both key and tempo had a detrimental effect on explicit memory compared to those melodies that had not been changed. Participants, regardless of music training, were unable to identify melodies that had been changed in either tempo or key from study phase to test phase. These results support the idea that explicit memories are only retrieved when the melodic context at the time of recall matches the melodic context heard at encoding (Schellenberg et al., 2014).

Johnson, Kim and Risse (1985) examined the mere exposure effect for music in patients with Korsakoff Syndrome. Korsakoff syndrome is a memory disorder that stops patients from recalling recent events (Johnson et al., 1985). The symptoms of Korsakoff syndrome resemble those of amnesia patients with severe loss of explicit memory. Due to the loss of memory function, it was expected by Johnson and colleagues that patients with Korsakoff disease would perform poorly on implicit memory tasks compared to their healthy counterparts. However, as discussed in

Chapter 2, amnesic patients have been found to retain their implicit and procedural memory. To examine the possible differences between implicit and explicit memory in patients with Korsakoff syndrome compared to their healthy counterparts, Johnson and colleagues (1985) examined both mere exposure for music (preference task) and the recognition of musical extracts (explicit memory task). Participants were presented unfamiliar Korean melodies in the study phase of a task. In the testing phase participants were played an equal number of melodies that had been previously played and melodies that were new and asked how much they liked each melody. After four days participants performed the task again, only this time, in the testing phase participants were asked to decide which melody sounded more familiar. Johnson and colleagues found that mere exposure effects were present in both healthy adults and patients with Korsakoff syndrome. The magnitude of the mere exposure effect was similar to the control participants despite the poor recognition memory results. This shows that the mere exposure effect is not dependent on explicit memory.

Many mere exposure studies use listening tasks to focus on differences between familiar and unfamiliar melodies. However, few studies have investigated how individuals acquire knowledge of musical structure incidentally through mere exposure (Rohrmeier, Rebuschat & Cross, 2011). Rohrmeier et al., (2011) aimed to look at the incidental learning of melodic pitch structures by using a musical grammar task. The musical grammar task followed the structure of the Artificial Grammar task shown in Chapter 2. However, instead of sequence of letters used in the Artificial Grammar task, Rohrmeier used one beat music notes which formed musical sequences. Both musicians and non-musicians participated. Like other mere exposure tasks, Rohrmeier et al., (2011) used both a learning phase and a testing phase. In the learning phase, participants completed a tone counting task. In the testing phase, participants heard 66 sequences (generated using the finite-state grammar), 17 of which had been previously heard in the learning phase. Participants were asked to decide whether the sequences heard were familiar or unfamiliar and give a confidence rating for their answer. Results showed that participants acquired knowledge of grammatical musical structure under the incidental learning conditions (Rohrmeier et al., 2011). Non-musicians performed as well as musicians suggesting that extensive training has little impact on the processing of musical structure (Rohrmeier et al., 2011). That said, confidence ratings suggest that participants had gained explicit knowledge of the task despite the incidental learning conditions (Rohrmeier et al., 2011). This finding suggests that individuals, despite of musical training, pick up musical patterns when listening to melodic music (Rohrmeier et al., 2011).

3.2 Implicit knowledge for music

Implicit memory for music can also be shown with the use of priming techniques. Musical priming can be shown in the form of faster or more accurate judgements about note pitch or chordal structure, for example, being able to sing back the last tone of a melody if that note has been previously heard in the melody or reacting to a chord that is expected given the tonal context of the melody (Ettlinger et al., 2011).

As discussed in Chapter 2, word and picture completion tasks have been key tasks when looking at implicit memory processes using visual stimuli. Warker and

Halpern (2005) created a tune stem completion task that was similar to word and picture completion tasks to look at musical implicit memory processes. The aim of the tune stem completion study was to look at how participants store and retrieve tonal music by using a vocal production task. Participants completed either an implicit or explicit task, which only differed in the instruction's participants were given at the time of task completion. In the initial learning phase, participants were asked to listen to a set of composed melodies; some unfamiliar tunes and some that were based on known folk tunes. In the following section, selected tunes finished on the penultimate note, and participants were asked to hum/sing the next note that would fit best musically. In the explicit memory condition, participants were asked to hum/sing the note that they remembered coming next. Results showed that participants completed more tunes correctly when they had been previously heard, suggesting implicit memory for sequences that had been previously heard. The implicit memory results and explicit memory results were uncorrelated, suggesting that implicit memory results were distinct from the explicit memory process (Warker and Halpern, 2005).

In a second experiment, Warker and Halpern (2005) looked at the effect of perceptual similarity on implicit and explicit retrieval of music, using musical timbre. The experiment separated the tunes into different timbres consisting of a flugelhorn, steel guitar and grand piano. The timbre of the tunes was changed from study phase to testing phase. Experiment 2 replicated experiment 1 showing that participants completed more tunes correctly that had been previously heard than the novel tunes. Changing the characteristics of the music did not have any significant effect on either implicit memory or explicit memory. Looking at the different timbres individually, a preference for a flugelhorn sound affected performance in the explicit memory task with participants performing better when the flugelhorn timbre was the same at both study and test phase and performing less accurately when the timbre changed from study to test phase. However, this was not the case for the other timbres. Participants performed worse when tunes were heard on a steel guitar at both study and test phase. These results provided evidence for different encoding effects in both implicit and explicit memory, suggesting that explicit memory is affected more by changes in timbral characteristics than implicit memory (Warker and Halpern, 2005). Although the musical stem task showed that there was a lack of association between implicit and explicit memory, the production element of the task presents many methodological issues. In order for the experiment to be accurate participants must ideally have relative pitch in order to take an accurate measure. Although many trained musicians do have precise relative pitch, this is not the case for non-musicians. Walker and Halpern (2005) reported that participants were hesitant to respond when asked to sing their response and therefore not all responses were recorded. For this to be eliminated, a nonverbal response must be designed. However, this will then be limiting the study to participants that have the ability to play an instrument and hence renders the test unsuitable for non-musicians. Studies which followed therefore looked for novel ways to make implicit music tasks more inclusive.

The phoneme monitoring task (Bigand, Tillmann, Poulin, D’Adamo & Madurall, 2001; Tillmann, Justus and Bigand, 2008) is a musical priming paradigm used to investigate participants’ implicit knowledge of tonal relations and harmonic structures. The study focused on the prediction of harmonic relations (the relationship between chords) and therefore aimed to look at harmonic priming (the speed of processing a chord that is either related or unrelated to the key of the music) rather than long-term memory. Bigand et al. (2001) presented an eight-chord strain that was sung using sampled synthesised vocal sounds, each chord sung to a different phoneme (See figure 3.1 for example of sung phonemes). Each sequence ended on either the phoneme */di/* or */du/.* Participants were asked to identify as quickly as possible to which phoneme the final chord was sung. Chord sequences were split into a conventional Western cadence, which Bigand et al. (2001) called the related condition (ending on the tonic chord) and an unconventional harmonic ending, which they called the less related condition (ending on the sub-dominant chord). The target chord for each condition was never heard in the previous context therefore priming to the target chord did not occur throughout the chord sequence. By manipulating the harmonic relationship of the final chord from the previous context, Bigand and colleagues were aiming to look at the differences in harmonic priming between a conventional western chord (strong harmonic priming) and an unconventional ending which would show less harmonic priming and therefore slower processing or slower reactions to the final phoneme. Bigand et al. (2001) found that participants were quicker to react to the harmonically related chords than the less related chords. This suggests that participants are faster to react when a familiar harmonic structure facilitates phoneme retrieval (Tillmann et al., 2008). In other words, there is less attention paid to the conventional harmonic sequence, showing implicit understanding of Western harmonic structures. Participants were either music graduates or students with no formal music training and the effect was found even in the absence of formal musical literacy. It should be noted, however, that in this study, the penultimate chord for both the related and less related condition was different (the dominant for the related condition and the tonic for the unrelated), which may have cued participants to predict the final chord and which may have further facilitated the phoneme recognition (See figure 3.1 for an example of this). The following chapters will focus on the development of the phoneme monitoring task to look at the implicit learning and knowledge of musical sequences and whether musical training benefits the unconscious learning of musical sequences.

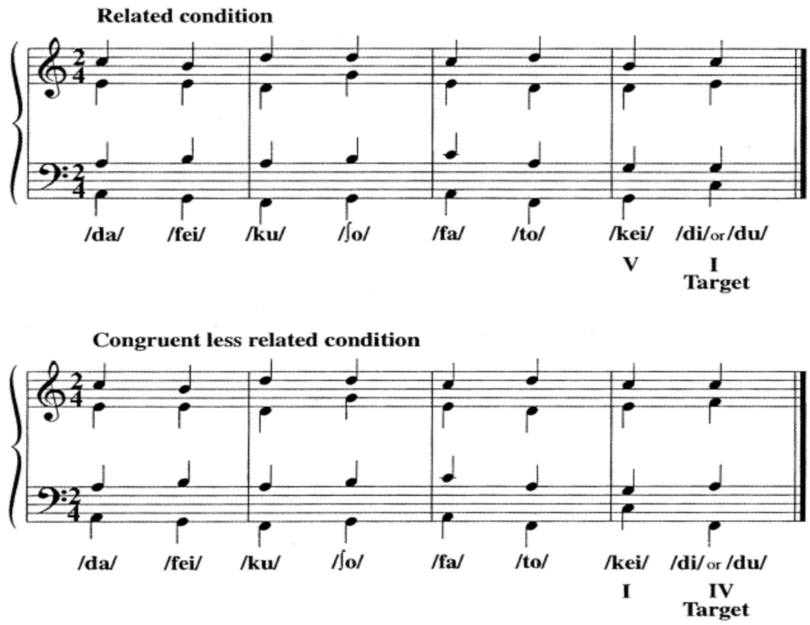

Figure 3.1. Example of a sung chord sequence in Bigand et al. (2001) phoneme monitoring task, showing different penultimate chord in both relatedness conditions.

Tillmann et al. (2008) replicated the work of Bigand et al. (2001) by using the phoneme monitoring task to look at the preserved implicit musical knowledge of cerebellar patients. It is suggested that the cerebellum has heightened activity during auditory tasks such as the perception of musical structures (Tillmann, Janata & Bharucha, 2003). Tillmann et al. (2008) studied music perception in participants with cerebellar damage to investigate whether associations between tones on the tonal harmonic system and relationships of sequences can still be accessed after the damage to the cerebellum. Results showed that both patients with cerebellar dysfunctions and age-matched control participants had quicker processing to related target chords, as previously observed by Bigand et al. (2001) with healthy adults. Results suggested that the cerebellum is not required to be intact in order to access implicit musical knowledge that is stored in long-term memory (Tillmann et al., 2008).

3.3 Music and ageing

There is an increased interest in identifying lifestyle factors that will contribute to healthy ageing and enhance cognition in later life (Hanna-Pladdy & MacKay, 2011). Music is a universal language and is a widely used leisure activity for both musicians and non-musicians (Hanna-Pladdy & MacKay, 2011). Musical leisure activities including listening, performing, and creating music have shown to be involved in the stimulation of a variety of cognitive functions (Hanna-Pladdy & MacKay, 2011). Musical expertise requires many years of formal training, which typically, is started in childhood and involves repetitive practice of motor sequences, for example, learning to play scales (Hanna-Pladdy & MacKay, 2011).

The repetitive nature of music practice has been associated with cortical reorganisation and enhanced sensorimotor functions in young musicians (Hanna-Pladdy & MacKay, 2011). Loui et al. (2019) assessed the relationship between musical training, physical fitness, verbal ability, intellectual ability, and brain plasticity in children. They found that children who participated in instrumental activity for at least 0.5 hours per week had higher verbal and intellectual ability than those that had no musical training (Loui et al., 2019). As well as higher levels of cognitive ability, Loui and colleagues found that the relationship between musical practice and intellectual ability was related to the maturation of white matter pathways in the auditory- motor systems (Loui et al., 2019). The effects found by Loui and colleagues were still significant after controlling for physical fitness, age, sex, and socio-economic status. These results suggest that musical training could improve cognition and brain health during childhood (Loui et al., 2019). This thesis is interested in the possible benefits of musical training in older adults and whether the improvements in cognition shown by Loui et al., (2019) have a lasting effect on cognition throughout a musician’s lifetime and when the brain starts to deteriorate.

Hanna-Pladdy and MacKay (2011) aimed to look at the possible differences in cognitive functioning in older adult musicians. Musicians with at least 10 years of performance experience were matched on age, education, intelligence and amount of participated physical exercise to individuals with less musical experience and non-musicians to look at whether musicians display better cognitive performance than non-musicians (Hanna-Pladdy & MacKay, 2011). Participants were grouped into one of three groups: Non-musicians, low activity musicians and high activity musicians, and were tested on verbal intellect, memory, attention and language.

Hanna-Pladdy and MacKay (2011) found a significant difference on nonverbal memory tasks, visuomotor task and cognitive flexibility tasks between musicians and non-musicians. Musicians outperformed both non-musicians and low activity musicians on all tasks, with low activity musicians performing better than non-musicians but not as well as high activity musicians. The primary difference between low and high activity musicians was the years of musical practice throughout the participants' life as both groups started instrument learning around the same age (Hanna-Pladdy & MacKay, 2011). Therefore, this result demonstrated a linear relationship between the number of years of musical performance and enhanced cognitive performance in older adult musicians compared to older adult non-musicians (Hanna-Pladdy & MacKay, 2011).

The understanding of music can be implicitly learned through mere exposure to different genres of music (Halpern et al., 2017). With more exposure to an implicit rule-based system like music, it would be expected that older adults, specifically older adult musicians, would have an increase mastery and understanding of music (Halpern et al., 2017). As previously discussed, musical training has multiple executive functioning benefits in older adults, with some domains such as language continuing to show benefits, even if the musician is no longer an active performer (Strong & Midden, 2020). Halpern et al., (2017) explored whether a lifetime of exposure to music, but with no previous formal musical training, would lead to an enhancement in older adults' ability to implicitly generate tonal expectations. Halpern and colleagues examined whether additional exposure to music would offset age-related cognitive declines by looking at behavioural and neural responses to unexpected musical endings. Older and younger adults were presented with unfamiliar short melodies where the final note was either expected or unexpected. Participants were asked to rate the final note on a scale of goodness of fit. Due to the melodies being novel to all participants, Halpern and colleagues were not looking at changes in memory but the computation of expectations. It was found that both younger and older adults were able to identify the melodies with the unexpected ending, which suggests that implicit rules from western music remains stable in older adults despite the lack of musical training (Halpern et al., 2017).

Music is well known to have many benefits including improving quality of life, reducing stress and evoking positive emotions in both healthy older adults and individuals with dementia (MacAulay et al., 2019). MacAulay et al. (2019) designed The Maine Understanding Sensory Integration and Cognition (MUSIC) project that aimed to develop an older adult friendly music intervention that looked at the effect of musical training on social, emotional and cognitive functioning in older adults. The MUSIC project proved 12 weekly 1-hour group music lessons (included learning how to play the recorder, reading music notation and learning musical language) and focused on looking at improved performance on measures of executive function and attention/processing speed, working memory, phonemic fluency and visuospatial fluency (MacAulay et al., 2019). After the 12-week program, results showed that participants showed an improvement in executive function, processing speed, working memory and visuospatial skills (MacAulay et al., 2019). However, due to the lack of a control group, it is difficult to determine how much of these effects are due to musical training and how much is a novelty effect. Despite the lack of control groups, if a music intervention can provide improvements in cognitive function in older adults it would be important to look at the effect it could have on individuals with cognitive impairments such as dementia.

Dementia can be described as a progressive decline in cognitive function that typically, is shown in explicit memory (Simmons-Stern, Budson & Ally, 2010). It is well understood that music processing is spared in those with dementia, with many studies showing that individuals with dementia still have the ability to remember, learn and perform music despite the loss of explicit knowledge for everyday events (Simmon-Stern et al., 2010). Simmon-Stern et al., (2010) demonstrated that music mnemonics could be used to enhance memory in those diagnosed with dementia. Both healthy older adults and individuals with dementia were presented with unfamiliar children's songs, where half heard a recording with sung lyrics and the other half accompanied by spoken words. Results showed that individuals with dementia were able to recognise more nursery rhymes when they were sung rather than spoken (Simmon-Stern et al., 2010). These results suggest that although individuals with dementia show a deterioration in explicit memory, the use of music could be used as a memory enhancer in everyday life (Simmons-Stern et al., 2010).

Research regarding implicit memory in those with dementia and the role that music can play in enhancing implicit memory is less clear than the results for explicit memory and music. It is not yet conclusive as to whether implicit memory declines in individuals with dementia. Deason et al., (2019) looked at the differences in explicit and implicit memory for musical stimuli in adults with mild Alzheimer's Disease. The mere exposure effect was used to look at the effect of implicit memory for instrumental, song and spoken stimuli and a recognition task was used to test the familiarity for instrumental, song and spoken stimuli (Deason et al., 2019). Each participant (healthy older adults and individuals with Alzheimer’s Disease) completed three sessions, one for each music condition across three days, each approximately one week apart. During each session participants took part in both the implicit and explicit memory condition. In the study phase of the task, participants were presented with 24 recordings and asked to say whether liked or disliked each track. In the implicit memory task, the 24 previously heard recordings were intermixed with 24 new recordings and participants were again asked to rate whether they liked or disliked the recordings. In the explicit memory task, participants were presented with the 48 recordings (previously heard in the implicit memory condition) and 48 new recordings and asked to rate how confident they were that the recording was new or old. Deason et al. (2019) found a mere exposure effect for the instrumental and song condition in both groups but not for the spoken stimuli. However, in the explicit test participants showed better results for the spoken stimuli than the musical excerpts (Deason et al., 2019). Interestingly, although both groups showed a mere exposure effect for instrumental and sung stimuli, there was no group difference suggesting that implicit memory function remains intact in those with mild Alzheimer’s Disease. Unlike the implicit condition, healthy older adults outperformed individuals with Alzheimer’s Disease in the explicit memory task. These finding suggest that individuals with Alzheimer’s Disease can still demonstrate preference for familiar stimuli even in the absence of explicit recognition (Deason et al., 2019).

As interest builds in understanding the role of implicit memory in ageing, it is important to understand how interventions such as music can play a part in being either a benefit or detriment to implicit memory over a lifetime. It is well established that musical training has a positive effect on working memory and explicit memory in healthy older adults and individuals with dementia. However, research is yet to explore the benefits of musical training on implicit memory. By increasing our knowledge of music and memory performance in the older adult and dementia population will help form an understand of how music can be used as a possible intervention that over time could improve independent living and functioning in older adults (Deason et al., 2019).

Like language, music is highly structured and complex. Whilst being unaware of the complexity of the music, listeners, musicians and non-musicians, are able to implicitly acquire knowledge of musical structure and harmony and make implicit judgement, as shown in the mere exposure tasks (Mandikal Vasuko, Sharma, Demuth & Arciuli, 2016). It could be suggested that musical training enhances musicians' ability for performing implicit learning tasks, as they are regularly exposed to music through repeated practice, enhancing priming and processing for auditory stimuli (Mandikal Vasuko et al., 2016). That said, little research has focused on implicit music learning in musicians and non-musicians and no research to date that looks at how musical training affects implicit memory in older adults and in individuals with different types of dementia. There is currently a need to devise an implicit music memory task that is accessible to both musicians and non-musicians enabling an insight into the effects of musical training on the processing of musical stimuli. The follow two chapters focus on the development of an implicit musical memory task that is accessible to both musicians and non-musicians.

Chapter 4

Development of an implicit musical memory task.

This chapter aims to develop an implicit memory task that focuses on the impact of musical training on implicit memory. As outlined in Chapter 3, previous implicit memory tasks that involved musical stimuli were not accessible to both musicians and non-musicians. In the current chapter, an implicit musical memory task will be developed that is accessible to both musicians and non-musicians.

4.1 Introduction

There is an increased interest in the effects of musical training on implicit and explicit memory. Explicit memory is the conscious retrieval of information that has been intentionally learned (Warker & Halpern, 2005). Implicit memory is the retention of previously learned information without conscious recollection of learning it. Implicit learning is said to occur when participants improve in speed or accuracy for the previously learned information (Bergstorm, Howard & Howard, 2012). Previous research has shown that musicians perform better than non-musicians on visuo-spatial sequence learning tasks (Anaya, Pisoni & Kronenberger, 2017). However, little research has focused on implicit music learning in musicians and non-musicians. There is currently a need to devise an implicit music task that is accessible to both musicians and non-musicians enabling an insight into the effects of musical training on the processing of musical stimuli.

Implicit memory tasks use a variety of priming techniques that act on automatic processes. Priming occurs when a visual or auditory item is presented to the participant in the initial study phase of the task, which then facilitates an unconscious reaction or response to the same stimulus when presented later in the task (Ward, Berry & Shanks, 2013). Many studies, for example, use a word stem completion task to show the unconscious encoding and retrieval of words, where participants are more likely to fill in word stems with items that have been previously viewed or heard (Tulving, Schacter & Stark, 1982). Words and music have some similar characteristics. For example, they both require the use of timbral and pitch changes (Warker & Halpern, 2005; Halpern & Mullensiefen, 2008). However, due to the use of harmony, unfamiliar intervals and rhythmic groupings, music can be more complex than language, which can make it harder for participants to encode the information in the initial study stage (Warker & Halpern, 2005).

Unlike words, unfamiliar music has no connection to an individual's mental lexicon. Words can be easily encoded and thresholds for retrieval lowered as individuals already have a lexicon of words (Warker & Halpern, 2006). However, previously unheard musical phrases are more difficult to encode, as the sequence of notes is novel and will not act to lower thresholds for known melodies, unless very close in melodic structure. The learning of a novel musical phrase is a similar process to the learning of visual sequences as seen in the Serial Reaction Time Task (see Chapter 2), than the unconscious learning of words as seen in word completion task (see Chapter 2). This is due to participants already having a previous mental lexicon for the words seen in the Word Completion Task (Warker and Halpern, 2006).

Previous research has looked at the similarities and differences between musical features and language. This includes the interaction between music and language on pitch dimensions (Zioga, Di Bernardi Luft & Bhattacharya, 2016). Research by Zioga, Di Bernardi Luft and Bhattacharya (2016) looked at the interaction between musical expectancies and prosodic expectancies (statements and questions) using a statement/question discrimination task in musicians and non-musicians. Participants were involved in two separate experiments: One EEG and one behavioural experiment. Each experiment was made up of both linguistic and melodic stimuli. The linguistic stimuli were separated into two conditions: statements and questions. The final word of all statements ended with a falling pitch, with the final word of all questions ending with a rise in pitch. The musical stimuli consisted of a five-note melody, with the final note consisting of either a large interval size (six or more semitones) or a small interval size that is more regularly heard in western music. Participant's heard the linguistic stimuli and the musical stimuli simultaneously. In both testing conditions, participants were asked to focus on the linguistics only, deciding whether the stimuli heard was either a question or a statement. Zioga and colleagues found that overall musicians performed better than non-musicians. Musicians were significantly faster and more accurate for detecting pitch violations and linguistic inaccuracies (Zioga et al., 2016). This finding supports previous research that suggests musicians are able to transfer their musical pitch processing abilities to speech pitch tasks (Zioga et al., 2016). As well as pitch processing, research by Bigand et al. (2001), discussed in Chapter 3, showed that musicians were able to process expected musical chords (tonic) faster than unconventional chords when focusing on the processing of phonemes over the musical stimuli. This current study is interested in looking at whether the incidental differences shown on pitch and harmony tasks could further determine the implicit knowledge and memory of musical sequences and whether these tasks would also show differences between musicians and non-musicians like the findings previously discussed.

4.1.1 Aims of the Study

The current study aimed to investigate whether an implicit musical memory task would identify implicit memory differences between musicians and non-musicians. By developing the Phoneme Monitoring task by Bigand et al. (2001) (discussed in Chapter 3), we were able to look at both implicit knowledge of musical structure but also implicit memory for specific musical sequences. By using both musician and non-musician participants we were able to look at whether musical training has impacted on implicit knowledge and memory.

It was hypothesised that musicians would react quicker than non-musicians and that participants would react quicker to the phonemes attached to a conventional perfect cadence strain (sounds as though the sequence as come to an end) than the non-cadence sequences (sequence sounds unfinished). See appendix 1 to hear an example of the difference between a cadence ending and a non-cadence ending.

4.1.2 The phoneme monitoring task adapted

As discussed in Chapter 3, the phoneme monitoring task by Bigand et al. (2001) is a test of participants' implicit knowledge of tonal relations and harmonic structures.

In this present study, we adapted Bigand et al.'s (2001) phoneme monitoring task to focus on both implicit knowledge of musical structure but also to study implicit memory for specific musical sequences. Both musicians and non-musicians took part to help us gain an understanding of whether musical training has impacted implicit memory and knowledge for musical structure and sequences.

We have modified the task so that each sequence contains only seven chords to help the listener identify the end of the sequence which in common time represents a more commonly found rhythmic pattern ending on a strong beat. The first six phonemes were kept constant throughout all sequences and the final phoneme interchanged between the phoneme */du/* or */di/*.

As in Bigand et al's study, the harmonically related condition ended with a perfect cadence on the tonic chord (this sequence sounded complete with the final note ending on chord 1, see appendix 1 for musical example of a cadence ending). However, we adapted the less related condition, the non- cadence chord sequence, so that the preceding chord was the same penultimate chord (the dominant) in both conditions. This ensured that there was no pre-cueing of the final chord. In order for participants to differentiate between the cadence and non-cadence sequences, a key must first be inferred (Bigand et al., 2001). The root position of the final/target chord was not heard previously in the sequence. For a chord to be in root position the lowest note is at the bottom of the chord for example a C major chord would contain the notes C E G with the note C forming the first note of the chord. The chord was however, presented as an inversion to help establish the key of the sequence. An inversion of a C major chord would rearrange the order of the chord with either the note E or G becoming the lowest note in the chord. For example, the note E followed by a C then G where E is the lowest note in the chord.

The structure of the task was modified in order to test participant's implicit memory for specific musical sequences. The task was split into three blocks. Blocks one and two included 12 sequences, six of these were heard in both block one and two. We were able to look at the reaction times for the repeated sequences to examine whether participants had any gain in reaction times for the sequences that had been heard in both block one and two (see 4.2.2 procedure for more in depth detail). Additionally, we have added an explicit knowledge test to determine whether participants gained any explicit awareness of any sequences that they had previously heard. In the explicit task the final chord (the target chord) is missing, the participant is asked to guess whether the final chord ended on the phoneme */du/* or */di/*.

4.2 Method

4.2.1 Participants

Thirty-two young adults (19 female and 13 male) participated in the experiment: 16 musicians (seven male and nine female) and 16 non-musicians (six male and 10 female). The criteria for each group were based on previous research (Hansen et al, 2012); musicians were defined as people who were of grade 5 performance standard or above (based on the Associated Board of music examinations, musicians that have gained grade 5 are required to complete music theory examinations and therefore have theory knowledge) and had previously attended formal training and actively participated in music performance. Non-musicians were defined as people who did not have any musical training and were currently not involved in any music organisations. Musicians consisted of classically trained music graduates from the University of Huddersfield, the Royal Welsh College of Music and psychology undergraduate students from the University of Chester with formal musical training. Formal training was defined as individuals that had learned to read and perform music through education from music professionals or those who have who have gained qualifications from an accredited music body. Non-musicians were university graduates and students from the University of Chester. No participating non-musicians had previous individual musical training. Two participants attended a musical theatre group but were considered as non-musicians due to no formal musical training and therefore their results were not removed from the analysis. All participants were English natives and had attended English schools and therefore had only participated in music lessons according to the English National Curriculum. The National curriculum is a set of standards and subjects followed by schools around the UK to ensure all students have the same learning experience are learning the same things (“National curriculum”, 2014). Music lessons involve basic listening skills and group activities, for example classroom singing and music-making. However, this may not include formally learning an instrument or musical notation. All participants were tested individually at the University of Chester or at an organised rehearsal room and gave written consent for task participation. Before completing the study, all participants received an information sheet that outlined reasoning for the research and the structure of the task. It also presented participants with contact details should they feel they needed extra support from a third party and details for the research team should they require any further assistance. After the completion of the task, all participants were given a full debrief, this entailed a more detailed explanation of the research and the task they had taken part in (see Appendix 5, 6 and 7 for the Information sheet, consent form and debrief given to all participants).

Table 4.1. Demographic information for Musicians and Non-musicians.

Characteristics	**Musician**	**Non-musician**
Participants (N)	16	16
Male (N)	7	6
Female (N)	9	10
Age (Years)		
Mean	27	24.25
SD	2	3.99
Years of Musical training		
Mean	19.06	
SD	1.29	

4.2.2 Procedure

Participants were asked to listen to the sequence and decide as quickly as possible whether the final chord ended on the syllable */di/* or */du/.* Before the experiment began participants had three practice sequences that gave them feedback on whether they had answered correctly. The experiment was split into three blocks. The first block recorded reaction times and errors to the phoneme detection task. It consisted of 12 sequences: six cadence ending chords (three ending on the syllable *di* and three ending on *du)* and six non-cadence chords (three ending on */du/* and three ending on */di/*). Three seconds of white noise was sounded after each sequence and the start of each new sequence was indicated with a beep. Reaction times (RT) and errors to these novel stimuli were recorded. The second block consisted of 12 sequences, six sequences previously heard in block 1 (three cadence endings and three non-cadence endings), and six novel sequences (three cadence ending and three non-cadence ending). Participants were not informed that they had heard some of these sequences previously. Again, RT and errors were measured. The final block tested for explicit memory and consisted of 18 sequences (the six that had been presented in blocks 1 and 2, the six that had been novel in block 2, and the remaining six novel sequences). All were missing the final target chord. In this block participants were asked to 'guess' whether the sequence would finish either the syllable */di/* or */du/* and give a confidence rating, 1=not confident to 4=confident, of their answer. Here we assumed that if participants had explicit memory for the previously presented stimuli, they would be likely to perform at a level above chance on the previously heard sequences, but at chance on those they had not previously encountered. Within each block, all the sequences were presented in a random order that was generated by e-Prime 2.0 (Schneider et al., 2002)

4.2.3 Design and Stimuli

The experiment used a mixed design, with repeated measures including harmonic relatedness, familiarity, and time of presentation, and with musician or non-musician as the grouping variable. Twenty-four different seven-chord sequences were developed using Sibelius 6 (and recorded using the sample voice sounds on the Vocal Writer singing software, version 2.0 (Cecys, 1998). Care was taken to ensure all 24 sequences were distinct and not, for example, transpositions of the same sequence. Each chord was sung to a different phoneme. The first six syllables of every sequence were identical (*doh, fey, so, ray, meh, to*) and were selected they were the most easily distinguishable phonemes available on VocalWriter. The final target chord was either the phoneme */di/* or */du/* (see figure 4.1). These were retained from Bigand et al. (2001) as they had found that out of the 24 consonant-vowel phonemes used in their study, they were the easiest to distinguish. The sequences were then transferred to MP3 files and the experiment was conducted using e-Prime 2.0 software. The tempo of the sequences was 92 crochet beats per minute meaning that the length of each sequence up to the onset of the target phoneme was 4005ms. There was a programming delay of 0092ms before the start of each sequence. The response was then timed from that onset of the seventh chord in the sequence. Participants used the computer keyboard keys 'A' for */du/* and 'L' for */di/* to respond to all sequences. The experiment only moved on to the next sequence once the participant had pressed a response key. A three second inter-stimulus-interval of white noise separated each sequence. To control for any intrinsic difficulty effects the sequences were counterbalanced across participants so that, for example, the first participant would hear figure 4.1 below with the */du/* ending and the second with the */di/*ending. See appendix 2 for audio examples of the sequences.

Non-cadence sequence ending

V IV

Doh Feh So Ray Meh To Du/Di

Cadence sequence ending

V I

Doh Feh So Ray Meh To Du/Di

Figure 4.1. Example of cadence and non-cadence chord sequences used in the Adapted Phoneme Monitoring Task.

4.2.4 Analysis

The primary measures collected for the Adapted Phoneme Monitoring Task were reaction times and accuracy. Average reaction times were calculated for each block and each cadence type that occurred with the block. Mean accuracy and confidence ratings were collected for the explicit memory task.

A mixed measures analysis of variance was conducted comparing repeated variables (time of presentation: block one, block two; Familiarity: repeated sequences, novel sequences; Sequence ending: cadence, non-cadence), with group (musicians and non-musicians) as the between-subject variable.

4.3 Results

For each participant an average reaction time was recorded for each variable and an overall average was taken for each group (See table 4.2). Error rate was <1% and incorrect answers were not included in the averages. Reaction times were recorded from the start of the final chord (See table 4.2 for reaction time results).

The ANOVA showed a significant main effect of time of presentation ($F(1,30) = 31.817$, $p < .001$, $\eta p^2 = .515$). Participants reacted quicker to phonemes heard in the second block of trials compared to those heard in the first block. There was a significant main effect of sequence ending (cadence and non-cadence) ($F(1,30) = 5.197$, $p = .030$, $\eta p^2 = .148$). Overall, participants responded quicker to phonemes for the chords ending on a cadence than those with the unconventional ending. A marginal effect of group ($F(1,30) = 4.014$, $p = .054$, $\eta p^2 = .118$) showed that musicians reacted quicker than non-musicians overall. There was no significant effect of familiarity ($F(1,30) = .031$, $p = .911$, $\eta p^2 = .000$).

There was a significant interaction between time of presentation and group ($F(1,30) = 7.229$, $p = .012$, $\eta_p^2 = .194$). Paired samples *t*-tests with an adjusted alpha level of $p < .025$ confirmed that both groups reacted quicker for chords in block 2 than block 1 (musicians $t(15) = 2.567$, $p = .021$, $d = .249$; non-musicians $t(15) = 5.090$, $p < .001$, $d = .783$). However, non-musicians showed greater improvement in reaction time for sequences heard in the second block compared to musicians. There was a significant interaction between time of presentation and familiarity ($F(1,30) = 7.382$, $p = .011$, $\eta_p^2 = .197$). Post hoc *t*-tests with an adjusted alpha level of $p<.025$ showed that for unfamiliar chords, participants were faster on the second block ($t(31) = 3.546$, $p = .001$, $d = .367$; mean difference = 136 ms), suggesting an effect of practice on the task. Participants were also significantly faster on familiar chords in the second block ($t(31) = 5.606$, $p < .001$, $d = .566$), and here the larger mean difference between blocks for familiar sequences (230 ms) is suggestive of an additional effect of familiarity over and above practice effects (see figure 4.2).

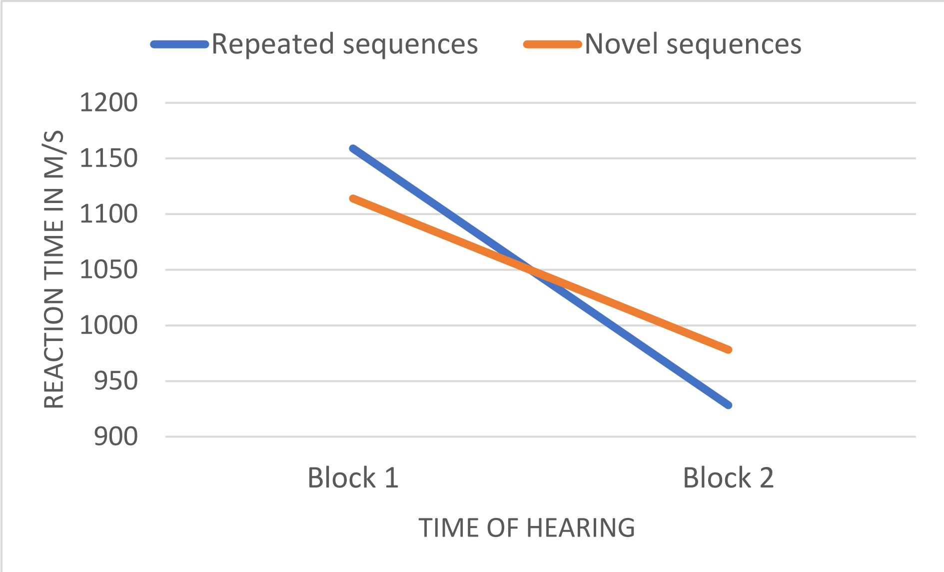

Figure 4.2 Reaction time differences for repeated and novel sequences in Block 1 and Block 2

Overall, participants reacted quicker to the repeated chord sequences that had been heard in both sections compared to the novel chord sequences that were only heard once. Results showed a significant interaction of sequence ending and group ($F(1,30) = 6.031$, $p = .020$, $\eta p^2 = .167$) . Post hoc *t*-tests with adjusted alpha level of $p<.025$ showed a significant effect of sequence ending for non-musicians ($t(15) = -3.748$, $p = .002$, $d=0.242$) who reacted quicker overall to the cadence ending than the non-cadence ending. There was no effect of relatedness for musicians ($t(15) = .094$, $p = .927$). There was no significant effect of familiarity and group ($F(1,30) = 279$, $p = .602$, $\eta p^2 = .009$), time of hearing and sequence ending ($F(1,30) = .128$, $p = .723$, $\eta p^2 = .004$).

There was no significant three way interaction between time of hearing, sequence ending and group ($F(1,30) = 3.047$, $p = .091$, $\eta p^2 = .092$), time of hearing, familiarity and group ($F(1,30) = .832$, $p = .369$, $\eta p^2 = .027$), Sequence ending, familiarity and group ($F(1,30) = 1.123$, $p = .298$, $\eta p^2 = .036$) and time of hearing, sequence ending and familiarity ($F(1,30) = .707$, $p = .407$, $\eta p^2 = .023$). There was no significant four-way interaction between sequence ending, time of hearing, familiarity and group ($F(1,30) = .540$, $p = .468$, $\eta p^2 = .018$).

Explicit memory

In the explicit condition, participants were asked to 'guess' what the final syllable would be. This was a forced choice answer – participants selected either */di/* or */du/* meaning that on sequences which they had heard before and for which there was a 'correct' answer, they would be expected to perform higher than chance if they had explicit memory of the sequence. A one-sample *t*-test was used to look at whether participants showed any explicit memory for musical sequences by comparing their responses to chance (a 50% accuracy for the choice of */di/* or */du/*). This was analysed using data from the third block by looking at accuracy for chord sequences that were heard in both blocks as well as sequences that were heard in block 2 only. Familiarity on accuracy scores showed that participants were performing at chance whether they had heard the sequences twice before the final block (M = .527, SD = .171; $t(31) = .880$, $p = .386$) or just once before the final block (M = .537, SD = .192; $t(31) = 1.085$, $p = .286$).

A Pearson's correlation coefficient was also conducted and confirmed that there was no correlation between accuracy of response and confidence ratings ($r = -.75$, $n = 32$, $p = .684$).

Table 4.2. Mean reaction times (ms) for familiarity (Repeated sequences, Novel sequences); Sequence ending (Cadence, non-cadence) and time (Block 1, block 2). Error rate was <1% and incorrect answers were not included in the averages.

		Familiarity					
		Repeated			Novel		
		Cadence	Non-cadence	Sub-total	Cadence	Non-cadence	Sub-total
Block 1	Musicians	981.563 (373.934)	963.818 (384.520)	972.691 (379.227)	971.288 (349.986)	953.543 (360.572)	962.416 (355.279)
	Non-musicians	1296.422 (371.424)	1348.193 (403.563)	1322.308 (387.494)	1261.761 (334.709)	1313.532 (366.849)	1287.647 (350.779)
	Subtotal	1138.993 (372.679)	1156.006 (394.042)	1147.500 (383.361)	1116.525 (342.348)	1133.538 (363.711)	1125.032 (353.029)
Block 2	Musicians	853.776 (392.879)	869.032 (440.713)	861.404 (416.796)	875.109 (372.989)	890.365 (420.823)	882.737 (396.906)
	Non-musicians	1005.583 (327.104)	1034.011 (324.493)	1019.797 (325.799)	1034.073 (339.760)	1062.801 (337.149)	1048.437 (338.455)
	Subtotal	929.680 (359.992)	951.522 (382.603)	940.601 (371.298)	954.591 (356.376)	976.583 (378.986)	965.587 (367.681)
Total		1034.307 (366.336)	1053.764 (388.323)		1035.558 (349.362)	1055.061 (371.349)	

Table 4.3. Accuracy percentages for correct guesses in the explicit memory task.

	Accuracy		
	Musicians	Non-musicians	Subtotal
Block 1 and 2	52.1%	53.3%	52.7%
Block 2 only	53.8%	53.6%	53.7%

4.4 Discussion

Implicit learning is observed when participants show an improvement in response to the stimuli that have been previously presented, without any explicit training on those stimuli. In this study, six sequences heard in the first block are repeated then repeated in the second block. Implicit learning for the repeated sequences can be shown if reaction times for those sequences are faster in the second block than the first. Results showed that both musicians and non-musicians reacted quicker to sequences that had been heard before in both the first and second blocks of trials than the sequences that were unfamiliar. Unlike Bigand et al.'s (2001) study, we found some differences in performance between musicians and non-musicians. Both groups showed an improvement in reaction times between the first block of trials, and the second block of trials, which contained some repeated material. While musicians were marginally faster at the task overall, non-musicians showed a greater improvement in reaction time between blocks. As it is unlikely that non-musicians had greater implicit learning of musical stimuli than musicians, their gains may well be attributed to practice effects. It can be concluded that participants were not guessing the phoneme ending, as we would expect the error rate to be on average of 50% if they were providing guess answers. As the error rate was less than 1%, we can be confident that the processing time are that of real responses.

As in Bigand et al.'s (2001) study, participants were not asked to pay any explicit attention to the musical structure of the chord sequences, only the syllable of the final chord. This allowed the experiment to be used to test for harmonic priming by using modern western cadence progressions in comparison to non-cadence chord structures. Results showed that participants reacted quicker to the cadence chord sequences compared to the non-cadence sequences. However, this varied by group; while results for non-musicians were in accordance with previous studies (Bigand et al., 2001; Tillmann et al., 2008) musicians were not affected by the structure of the cadence. A cognitive approach to harmonic priming suggests that there is a western harmony hierarchy of chords where the western listener internalizes chords that are built on the tonic, subdominant and dominant due to mere exposure to western music and would therefore react faster to the cadence ending than the non-cadence (Bigand, Poulin, Tillmann, Madurell & D'Adamo, 2003). An alternative explanation suggests that sensory priming, a chord that shares component chords or overtones with the final chord will be anticipated and therefore should have a faster reaction time. For example, a cadence ending shares more component tones than a non-cadence ending and therefore participants will anticipate the cadence ending more than the non-cadence (Bigand et al., 2003). However, we are unsure why musicians were unaffected by the cadence structure, but the differences between musicians and non-musicians might be explained through the amount of musical training musicians acquire.

As well as supporting previous research which shows implicit knowledge of musical structures, we were able to demonstrate a degree of implicit memory for previously heard musical sequences. While this was confounded with more general practice effects (participants were faster 'across the board' in the second block of trials), the block by familiarity interaction indicates that gains made on previously heard sequences were greater than those for the novel sequences presented in the second block, with musicians performing faster overall. Our results support the findings of Conway, Pisoni and Kronenberger (2009,) which suggests that sound provides a framework, which they term the "auditory scaffolding process", which participants use to learn and process sequential auditory information. Differences in musical experience may enhance these sequencing skills. Francois and Schon (2011), supported the "auditory scaffolding process" where they found that increased exposure to sounds benefits implicit learning.

By adapting the phoneme task, we were able to look at the whether participants gained explicit knowledge from the sequences and therefore whether explicit memory affected reaction times. Explicit memory for musical sequences would be shown if participants performed above chance on those sequences that had been presented in section 2, followed by a further increase in accuracy for those that had been heard in both block 1 and 2. As participants were not instructed to remember any information as part of the task, participants were asked to guess the final missing phoneme of the sequence (whether the final syllable was */du/* or */di/*) followed by giving the confidence level of their answer. As participants performed at chance (accuracy levels of c. 50%) and there was no correlation between accuracy of answers and confidence levels, we were able to conclude that participants showed no signs of explicit knowledge of musical sequences.

4.5 Further improvements

Repetition within musical structures is common in much popular and classical music, and our study shows that such repetition may facilitate people's listening, even when they are not explicitly aware they have encountered a specific musical phrase a few minutes earlier. This effect is found for both musicians and non-musicians; while musicians process musical stimuli faster than non-musicians, the latter seem to gain more from repetition, though future research should attempt to disengage implicit memory from more general practice effects on the task. To do this an investigation focusing on the extent of the implicit knowledge gained in both non-musicians and musicians needs to be developed. By extending the phoneme monitoring task to include multiple blocks of repeated sequences (extending the task from two blocks of musical sequences to six blocks of sequences) you will be able to see if non-musician's reaction times level out and match the reaction times of musicians. By including a random sequence block (including sequences that will not be repeated throughout the task) both at the beginning of the task and at the end of the task, the extent of implicit learning gained throughout the task should be visible. The speed of reaction times throughout the repeated sequences should improve (get faster) whilst the reaction time for the random sequence should be slower than those shown in the repeated sequences. This pattern of reaction times should imitate the results found in Serial Reaction Time Task by Nissen and Bullemer (1987) and therefore show implicit learning for musical sequences.

The next chapter will develop the adapted phoneme monitoring task used in the present study to distinguish between task practice effects and implicit learning for musical stimuli.

Chapter 5

Benefits of music training on implicit memory

The previous chapter focused on the implicit knowledge of musical stimuli in musicians and non-musicians. Results suggested implicit learning for musical sequences. However, these were inconclusive, as a distinction between general practice effects and implicit learning of musical sequences could not be determined. The current study is a further development of the adapted phoneme monitoring task that it is hoped will enable a distinction to be seen between practice effects of the task and implicit learning for musical sequences.

5.1 Introduction

Musical training requires the use of complex sensory skill and well-rehearsed motor skills (Anaya, Pisoni & Kronenberger, 2017). Musicians are able process several pieces of information at the same time, for example reading music, playing an instrument, listening to the ensemble and keeping tempo (Anaya et al., 2017). These skills have been associated with more generally enhanced motor and visual motor skills (Brochard, Dufour & Despres, 2004) and enhanced memory for auditory motor sequences (Tierney, Bergeson, & Pisoni, 2008; Anaya et al., 2017). After years of formal training, the fine motor skills and auditory processes shown by musicians are sequential in nature (Anaya et al., 2017). For example, pianists are required to learn multiple scales that they should be able to play without looking at both hands. Scales are all sequential and follow a pattern. However, musicians are required to know the positioning of the keys, the directional movement of their hands, the specific fingering patterns, and what note is coming next. These patterns become implicit in nature and thus could provide evidence for musicians having better basic sequence learning abilities (Anaya et al., 2017).

Since the late 20th Century, music has become more accessible both to listen to through the use of media, and to compose through computer software (Leung & Dean, 2018). The ability to freely access music has opened room for non-traditional music to be heard much more regularly (Leung & Dean, 2018). Previous research has shown that humans are able to unconsciously learn about different parts of western music, including tonality (Bigand et al., 2001), rhythm (Conde et al., 2012) and timbre (Schellenberg et al., 2014), without musical training (Leung & Dean, 2018). Leung and Dean (2018) designed a new paradigm that looked at the incidental learning of notes belonging to a microscale that were unfamiliar to listeners of all cultural backgrounds. The objective of the task was to examine how fast and well individuals could learn a novel music system. Research looking at musical expectancies shows that when individuals are presented with 'out of key' tones or chords, a 'surprise' response is evoked as what the individual has heard is different to what they expected (Bharucha & Stoeckig, 1986).Therefore, individuals are able to discriminate between tones that fit the key of the music and those that do not (Bharucha & Stoeckig, 1986). Leung and Dean (2018) examined the learning of the microscale by creating two types of short melodies in a timbre detection task. One set of the melodies were composed of notes from the current western tuning system. The second set of melodies included notes from the microscale. Leung and Dean changed the timbre of one of the notes in the melody (from a piano to a clavichord), to which participants had to react to the change in timbre. This allowed the focus of the task to be on the change of timbre and not the possible learning of the melody. The note before the change in timbre was either related to the tonality of the melody (congruent) or did not fit the tonality of the melody (incongruent). It was predicted that if participants reacted faster to the changes in timbre in the incongruent melodies then individuals than the congruent melodies, then individuals had become familiar with the novel scale (Leung & Dean, 2018). Participants were tested twice with a gap of a week between each test. Leung and Thornton Dean (2018) found that untrained musical listeners could learn novel musical tonality rapidly through incidental exposure. It was found that musicians did not show a superior learning for the novel scales like the non-musicians. This finding is also supported by the results of Chapter 4, with musicians showing no difference between the cadence ending of the sequences. A possible explanation for this is that musicians have prior exposure to a variety of different musical tonalities as well as hearing different instrumental tuning when performing in ensembles. Therefore, incongruent tones do not appear as unexpected as they do to non-musicians.

Implicit learning tasks involve the unconscious learning of information (visual, auditory or motor skills). Implicit sequence learning looks at participants' ability to learn sequential information and apply this knowledge without awareness (Kuhn & Dienes, 2005). Nissen and Bullemer (1987) designed an implicit learning task that required participants to respond to a visual cue that appeared in one of four possible positions on a computer screen. Participants responded by pressing a key on a response pad. A sequence of 10 trials was repeated 10 times. This was repeated over six blocks and reaction times were recorded. Faster reaction times for each block were assumed to reflect implicit learning of the sequence. Nissen and Bullemer (1987) found that participants showed implicit learning for the repeated sequences without conscious awareness that a repeated sequence existed (See Chapter 2 for further details).

The current study follows the overall structure of the Serial Reaction Time Task (SRTT) by Nissen and Bullemer (1987). However, changes were made to the content of each block. The study comprises of seven blocks in total (see 6.12 for in detail explanation). Each block consists of 12 audio sequences. Unlike the Nissen and Bullemer (1987), these sequences were only heard once in each block and therefore the amount of repetitions in this study is significantly less than in the serial reaction time task. Despite this the distinction between implicit learning for musical sequences and general practice effects for the task should be distinguished.

5.1.1 Aims of the study

This chapter aims to further explore the possible benefits of musical training on implicit memory as found in Chapter 4. By further developing the Adapted Phoneme Monitoring Task to follow a structure closer to a classic SRTT, the current study was able to look further at both implicit knowledge and implicit learning/memory for specific musical sequences. By using musicians and non-musicians we were able to look at whether musical training affects implicit musical learning.

It is hypothesised that musicians will react quicker than non-musicians overall. Based on the previous chapter, it is expected that participants will react faster for the conventional cadence ending than the unconventional non-cadence ending.

5.1.2 Further development of the Adapted Phoneme Monitoring Task (APMT).

As discussed in Chapter 4, the APMT focused on the implicit knowledge of structure and implicit memory for specific musical sequences. In the current study we further adapted the phoneme monitoring task presented in Chapter 4 to produce an implicit musical learning task that focuses more on the implicit learning and memory for repeated musical sequences over a greater number of presentations.

One of the weaknesses of the APMT as used by both Bigand et al. (2001) and in the previous chapter, was the lack of tonal anchoring (the key could not be identified) throughout the sequences as discussed in Chapter 3. In the previous chapter, chords 4, 5 were not included in the main body of the sequence (used on the final two chords only) and chord 1 was only used as an inversion chord on the first chord of the sequence, therefore there was a lack of recognition for the key of the sequence. Here, the task was further modified so that both the cadence and non-cadence sequences contains the tonic, subdominant and dominant chord within the sequence. This enables the listener to gain a stronger sense of the key for each sequence. This does not impact the priming of the final chord, because, as in Chapter 4, the penultimate chord in both the cadence and non-cadence condition was always the subdominant (chord 4).

The main development of the APMT is the structure of the overall task. In Chapter 4, the distinction between task practice effect and implicit memory was difficult to decipher as the task only allowed for one repetition of the musical sequences. It was hoped that the changes to the structure allow for this study to further differentiate task and procedural learning, as can be done in a classic SRTT. The current task followed the structural design of the SRTT. The task was split into six blocks. Each block consisted of 12 sequences of seven chords. All musical sequences were different from one another. Block 1 consisted of 12 novel sequences (sequences that had not been heard before), while Blocks 2 – 5 consisted of 12 musical sequences that were repeated from Block 1 and in the same order. Block 6 consisted of 12 novel sequences (sequences that the participant has not heard before). We were able to look at the reaction times for the sequences to see if participants showed any gain throughout the repeated sequences. As the further developed implicit musical learning task follows the general design of a serial reaction time task, if participants show implicit learning for musical sequences, we should see a quicker reaction time over blocks two- five (the repeated sequences) and then slower reaction times for block 6 (novel sequence). As the current task merely follows the outline structure of the SRTT and the participants are hearing each musical sequence only 5 times compared to multiple within-block repeats in the SRTT, we expected to see a much smaller increase in reaction time in the final Block but we nevertheless hoped that this would help to distinguish task and procedural learning more effectively. The difference in reaction time between the penultimate and final block is used as a measure of implicit learning, while the difference between the first and final block is used as a measure of task learning. As in Chapter 4, a further block of sequences tested for explicit memory of the repeating sequences of chords. This block consisted of 12 sequences in total (12 sequences that had been previously heard in blocks two-five). The six novel sequences were removed as participants have heard a block of novel sequences prior to completing the explicit memory condition. All the sequences were missing the final chord and participants were asked to guess whether the final chord ended on the phoneme */di/* or */du/.*

5.2 Method

5.2.1 Participants

Thirty young adults (4 male and 26 female) mean age = 21.3years old participated in the experiment: 14 musicians (3 male and 11 female) and 16 non-musicians (1 male and 15 female). Musicians consisted of classically trained music graduates from The Royal Northern College of Music, University of Huddersfield and Psychology students from the University of Chester who had undergone suitable musical training. Non-musicians were all undergraduate students from the University of Chester. All participants were tested individually at the University of Chester or at the musician’s rehearsal space. No participating non-musicians had previous musical training. The criteria for each group were based on previous research by Hansen et al., (2012) as used in the previous study; non-musicians were defined as people who did not have any musical training and were currently not involved in any music organisations. Musicians were defined as people who were of grade 5 performance standard or above (as explained on Chapter 4) and had previously attended formal training and who actively participate in music performance (see Chapter 4 for definition of formal training). All participants were UK natives and had attended UK schools and therefore had received music lessons according to the English National Curriculum as in the previous study. Table 5.1 shows the demographic information of musician and non-musician participants.

Table 5.1. Demographic information for musicians and non-musicians

Characteristics	Musician	Non-musician
Participants (N)	14	16
Male (N)	4	1
Female (N)	10	15
Age (Years)		
Mean	22.5	20.5
SD	3.16	3.23
Years of Musical training		
Mean	14.8	
SD	4.16	

5.2.2 Procedure

Participants were asked to listen to the sequence of seven chords and decide as quickly as possible whether the final chord ended on the syllable */di/* or */du/.* Before the experiment began participants had three practice trials that gave them feedback on whether they had answered correctly. The task was completed over seven blocks. All blocks recorded RTs and errors to the phoneme detection task. The first block consisted of 12 sequences of six cadence chords (three ending on the syllable *di* and three ending on *du)* and six non-cadence chords (three ending on */du/* and three ending on */di/*). 3 seconds of white noise was sounded after each sequence and the start of each sequence was indicated with a beep. Blocks 2-5 repeated the sequences heard in Block 1. Block 6 included 12 new sequences (six cadence chords and six non-cadence chords). See appendix 2 for examples of both the cadence and non-cadence sequences heard in the implicit learning condition.

The final block tested for explicit memory and consisted of 12 sequences (12 repeated sequences heard in Blocks 1-5). Once again, all sequences were missing the final target chord. As in the Chapter 4, participants were asked to 'guess' whether the sequence would finish either the syllable */di/* or */du/* and give a confidence rating, 1 = not confident to 4 = confident, on how confident they were of their answer. Here we assumed that if participants had explicit memory for the previously presented stimuli, they would be likely to guess the correct answer at a level above chance on the previously heard sequences. Examples of the sequences heard in the explicit condition with the missing final chord can be heard in appendix 2.

5.2.3 Design and stimuli

The experiment used a mixed design with repeated measures on harmonic relatedness and Block of sequences, with musicians and non-musicians as the grouping variable. Forty-five seven-chord sequences were developed using Sibelius 6 and recorded using the sample voice sounds on the Vocal Writer singing software, version 2.0 (Cecys, 1998). This software allows for different syllables to be assigned to each chord and the four notes of a chord to be sung on the same syllable at the same time. The same eight syllables (see figure 5.1 for syllables used) heard in Chapter 4 were used. Six syllables were the same for every sequence, half of the sequences ended on the syllable */di/* with the other half ending on the syllable */du/* (see figure 5.1). The sequences were then transferred to MP3 files and the experiment was run using e-Prime 2.0 software. The tempo of the sequences was 96 crochet beats per minute. Three seconds of white noise sounded once the participant had responded to the syllable. A beep sounded for 3 seconds to indicate the start of the next sequence. Participants used keys ‘A’ for */du/* and ‘L’ for */di/* on the computer keyboard to respond to all sequences. The experiment only moved on to the next sequence once the participant had pressed a response key. As in the previous study, the sequences were counterbalanced across participants, so that the first participant would hear the sequence shown in figure 5.1 with the ending */du/* and the second participant would hear the same sequence with the ending.

Cadence

Doh Feh So Ray Meh To Du/Di

V I

Non-cadence

Doh Feh So Ray Meh To Du/Di

V IV

Figure 5.1. Example of cadence and non-cadence sequences used in the Adapted Phoneme Monitoring Task.

5.2.4 Analysis

The primary measure collected by the Adapted Phoneme Monitoring Task were reaction times and accuracy for each trial. A median reaction time was calculated for each block. Mean accuracy was collected for each explicit memory blocks. Reaction times were recorded from the start of the final chord (chord seven) (See table 5.2 for reaction time results).

A mixed design ANOVA was used to compare repeated variables (Block: one, two, three, four, five, six; Sequence ending: Cadence, non-cadence), with group (musicians and non-musicians) as the between subject variable.

5.3 Results

For each participant a median reaction time was recorded for each block of trials. The means for each group are shown in Table 5.2. Box plots were used to look for outliers based on the median reaction times for each participant. This resulted in the removal of one participant (musician) leaving 29 data sets recorded and analysed. Error rate was <5% and incorrect answers were not included in the averages.

Table 5.2. Mean reaction times(m/s) for Block (Block 1-6) and sequence ending (Cadence and non-cadence) by musicianship status.

			Sequence ending		
			Cadence	Non-Cadence	Total
Block	Block 1	Musician	1004.077 (167.804)	1086.154 (246.243)	1045.116 (207.024)
		Non-musician	967.406 (254.569)	1029.25 (232.721)	998.328 (243.645)
		Total	983.845 (217.093)	1054.759 (236.284)	
	Block 2	Musician	872.885 (263.881)	924.923 (255.022)	898.904 (259.452)
		Non-Musician	757.844 (232.506)	796.906 (271.773)	777.375 (252.14)
		Total	809.414 (249.385)	854.293 (267.654)	
	Block 3	Musician	681.615 (164.004)	659.077 (180.856)	671.846 (172.43)
		Non-musician	624.813 (237.338)	680.469 (246.379)	652.641 (241.859)
		Total	650.276 (206.229)	670.879 (215.997)	
	Block 4	Musician	613.231 (251.943)	585.192 (231.815)	599.212 (241.879)
		Non-musician	572.906 (254.919)	606.969 (238.366)	589.938 (246.643)
		Total	590.983 (249.866)	597.207 (231.496)	
	Block 5	Musician	522.462 (217.645)	556.962 (257.657)	539.712 (237.651)
		Non-musician	628.5 (315.782)	573.656 (225.514)	601.078 (270.648)
		Total	580.966 (276.771)	566.172 (236.151)	
	Block 6	Musician	738.538 (233.989)	712.577 (245.177)	725.558 (239.583)
		Non-musician	645.875 (385.603)	665.625 (335.277)	650.75 (360.44)
		Total	687.414 (324.529)	686.672 (294.189)	

A three way (Block, Sequence ending, and group) repeated measures ANOVA showed a significant main effect of Block ($F(5,135) = 26.050$, $p < .001$, $\eta p^2 = .491$). Participants showed improvement in reaction times throughout Blocks 1 to 5, whilst block six showed slower reaction times. (See Figure 5.2). Pairwise comparisons with a Bonferroni correction revealed that reaction times were faster for the novel sequences heard in Block 6 than Block 1 ($p = .001$). The difference between the novel sequences heard in Block 1 and Block 6 suggests an effect of practice on the task. The difference between Blocks 5 and 6 showed an increase in reaction times (235.518m/s) ($p < .001$) showing implicit learning for sequences. There was a significant main effect of sequence ending ($F(1,27) = 4.103$, $p = .053$, $\eta p^2 = .132$). Overall, participants reacted quicker to the phonemes that ended on a cadence chord than those with an unconventional ending. There was no significant group effect ($F(1,27) = .239$, $p = .629$, $\eta p^2 = .009$).

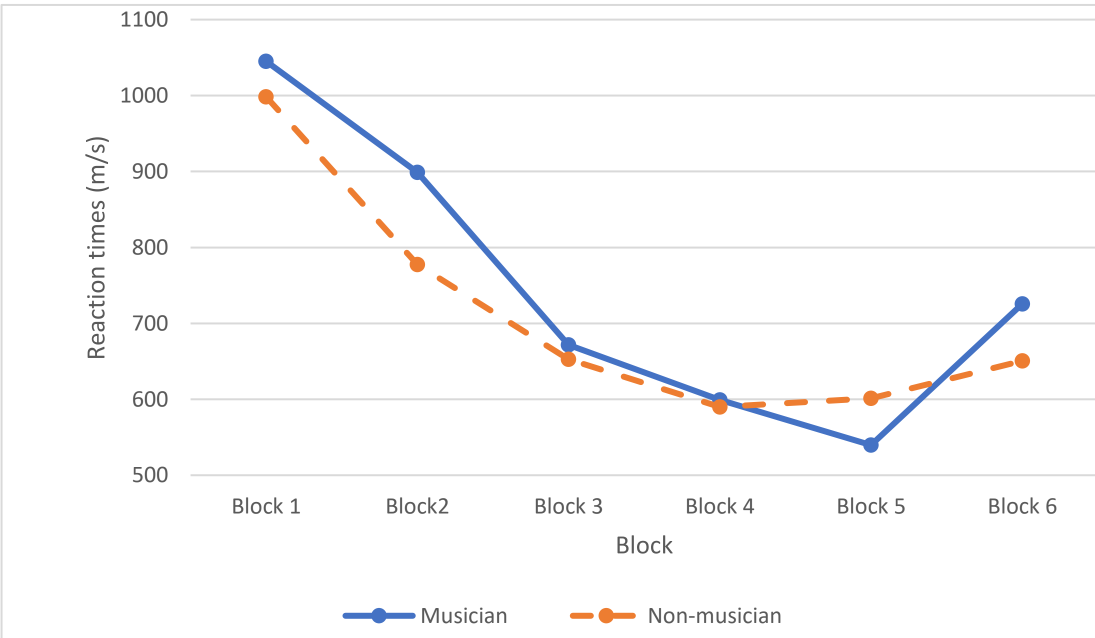

Figure 5.2. Mean reaction times(m/s) for musicians and non-musicians in each block.

There was a significant interaction of block and sequence ending (F(5,135) = 2.386, p = .041, ηp^2 = .081) (see Figure 5.3 below). Post hoc t-tests showed a significant difference between the cadence and non-cadence sequences heard in Block 1 (t(29) = -3.849, p = .024). As this effect was only shown in Block 1, it would suggest that the effect of the different sequence endings is reduced with practice. Participants reacted faster for the cadence sequences than non- cadence sequences. There was no significant interaction between block and group (F(5,140) = .612, p = .691, ηp^2 = .021) or Sequence ending and group (F(1,28) = .104, p = .749, ηp^2 = .004).

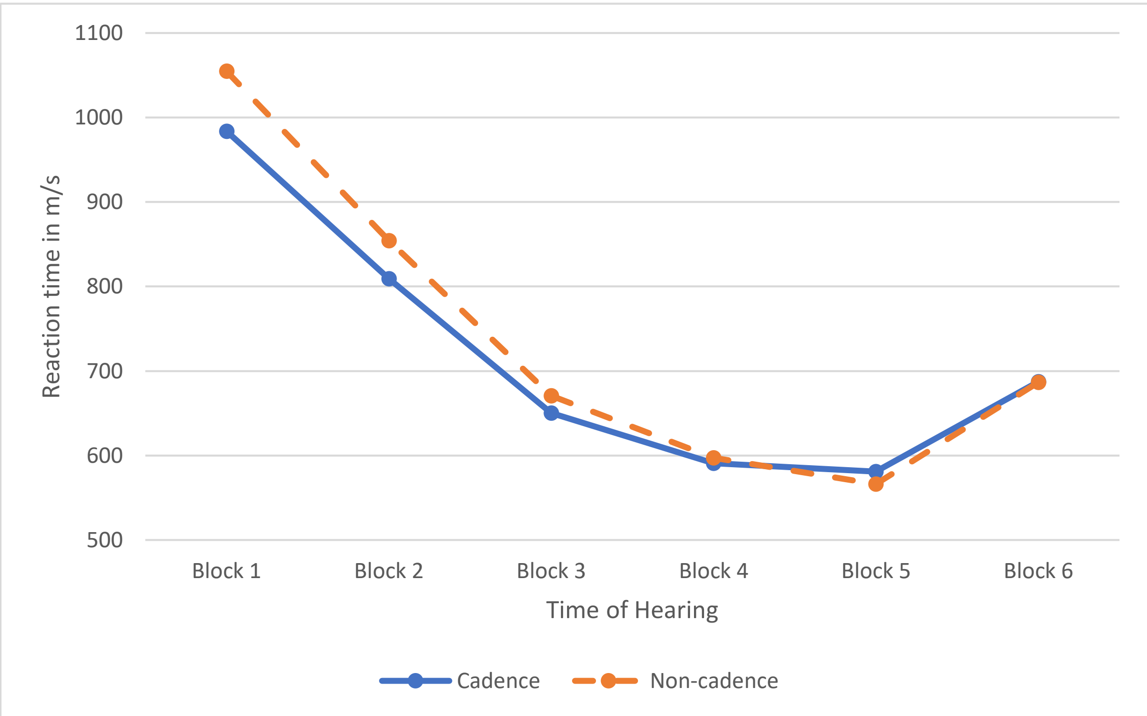

Figure 5.3. Mean reaction times (m/s) for cadence and non-cadence sequences.

There was a significant three-way interaction of Block, group and sequence ending ($F(5,135) = 2.336$, $p = .045$, $\eta p^2 = .08$). Post hoc tests using Bonferroni corrections revealed that musicians showed a significant difference ($p = .034$) between novel sequences heard in Block 1 and the novel sequences heard in Block 6 (difference of 320ms) suggesting a practice effect of the task. For non-musicians the difference between Block 1 and 6 (348ms) was marginal ($p = .062$). Both musicians and non-musicians showed slower reaction times for Block 6 compared to Block 5, however results showed there was no significant difference for either groups ($p = 1.00$).

Explicit memory

As in the APMT, in the final block participants were asked to 'guess' what the final syllable would be. This was a forced choice answer - participants were asked to 'guess' whether the final chord ended on either the syllable */du/* or */di/*. A one sample t-test was used to look at whether participants showed any explicit memory for the repeated musical sequences by comparing their responses to chance (c.50% accuracy for the choice of /*du*/ or /*di*/). This was analysed using data from the seventh block by looking at accuracy for chord sequences that were repeated in Blocks 2 to 5 as well as those that had not been heard previously. Accuracy scores showed that participants were performing at chance even after hearing the sequences five times (M = .523, SD =.148) ($t(28) = .842$, $p = .407$).

A Pearson's correlation coefficient was conducted and confirmed that there was no correlation between accuracy of response and confidence ratings ($r = .002$, $n = 29$, $p = .992$).

Table 5.3. Accuracy percentage for correct guesses in the explicit memory task

	Repeated Sequences		
	Musicians	Non-musicians	Subtotal
Accuracy	50.6%	53.7%	52.3%
Confidence	1.94	2.48	2.21

6.4 Discussion

The aim of this task was to look at implicit learning and memory for musical sequences in an implicit musical sequence task. Implicit learning is observed when participants show an improvement in response to a stimulus that has been previously presented without explicit awareness (Rohrmeier & Rebuschat 2012). In the case of this study, implicit learning occurred when reaction times got quicker over the blocks that included the repeated sequences. Implicit memory is evident when reaction times for the final novel sequences are slower without participants showing any awareness. Results showed that reaction times for both musicians and non-musicians got quicker over Blocks 1 – 5 (see figure 5.2). Block 1 and 6 were both novel sequences to the participant with the difference in the reaction times explained by a practice effect for the study. The sequences heard in Block 1 were then repeated in the same order in Blocks 2-5. The continuous reduction shows both practice and task effects for the musical sequences (see figure 5.2). As in the original serial reaction time task, the improvement in reaction times throughout

Blocks 2-5 signifies the participants' increasing expertise for performing the repeated pattern without conscious learning.

Implicit memory is measured in the final two blocks of the implicit musical task. Block 5 contained the final set of repeated sequences and Block 6 contained novel sequences that participants had never heard before. The results showed that both musicians and non-musicians were slower for the final block than the penultimate block which is suggestive of implicit memory for musical sequences (shown in figure 5.2). Although the differences between Block 5 and Block 6 were not significantly different for either group, the trend shown in figure 5.2 is suggestive of implicit learning in both groups. The difference in reaction times between Blocks 5 and 6 suggests that participants have gained procedural memories as the changes in chord sequences has resulted in an increase in reaction times. There is an important advantage for focusing on the differences between the repeated sequences and the novel sequences. When the sequential response is unexpectedly removed, the reaction times for the novel sequences are to be slower. Therefore, the changes in the chord sequence increase the novel trial reaction times, implying that the difference in reaction times is an accurate measure of implicit skill learning (Robertson, 2007). Both musicians and non-musicians show implicit learning and implicit memory for musical sequences. The reaction times for musicians are slower overall for the task. However, figure 5.2 suggests a greater degree of implicit learning occurring in musicians with participants showing a bigger difference in reaction times from Block 2 to Block 5 and a slower reaction times for Block 6 (see figure 5.2).

As in the previous study, participants were not asked to pay any explicit attention to the musical structure of the chord sequences, only to the final sung syllable on the final chord of the sequence. This allowed for this experiment to look at harmonic priming of modern western cadence chords compared to non-cadence chords. Results showed that overall participants reacted quicker for cadence endings than the unconventional non-cadence ending, which is consistent with Chapter 4. However, this was not consistent throughout all blocks in both groups. Musicians reacted faster for cadence sequences in Blocks 1 and 2, however from Block 3 onwards reaction times were quicker for the non-cadence endings. This is not a consistent pattern across both groups as non-musicians reacted faster for cadence ending throughout all blocks apart from Block 5. Despite lack of musical training, non-musicians or western listeners are able internalise chords built on the tonic, sub-dominant and dominant chord because of previous exposure to western music and therefore will react faster to cadence chord endings than non-cadence endings (Bigand et al., 2003). Unlike non-musicians, musicians are exposed to both conventional and non-conventional chord ending as more modern music explores less traditional chord structures. This suggests that the effect of harmonic priming neutralises in musicians and the difference between cadence and non-cadence sequences equalise.

A possible issue with the implicit music task is whether participants are explicitly aware of the repeated sequences throughout the blocks of stimuli. The lack of participants' explicit recall of the repeated sequences lends further support to the use of implicit memory in musical learning. In the initial task guidance, participants were not instructed to explicitly remember any of the chord sequences, therefore in the explicit memory condition, participants were asked to guess the ending of the sequence. Accuracy for the repeated sequences and participants confidence for their answer were compared. Explicit memory for music sequences would be observed if participants performed above chance (50%) on the repeated sequences. As participants performed at chance (see Table 5.3) and there was no correlation between accuracy of answers and confidence levels, we were able to conclude that there was no explicit awareness for the repeated musical sequences and the difference in reaction times is due to implicit memory.

If musical training does provide benefits for implicit memory, then a wider range of implicit memory tasks need to be explored. A trend can be seen in the current study suggesting that both musicians show more implicit learning for musical sequences than non-musicians. However, further research is needed to look at the long-term effects of musical training on implicit learning and whether there's a possible difference between musicians and non-musicians on general implicit memory tasks. Future chapters will aim to further explore the trend suggested on the adapted phoneme monitoring task and explore the possible benefits of musical training on implicit memory and learning in older adults.

Chapter 6

Possible benefits of musical training on implicit memory in healthy older adults.

Previous chapters have developed an implicit musical memory task that focuses on implicit learning for repeated musical sequences in musicians and non-musicians. This chapter aims to look at the possible distinction between musicians and non-musicians by focusing on whether musical training could be a beneficial factor in the preservation of implicit memory more generally in older adults.

6.1 Introduction

Age related cognitive ability has shown clear effects of memory decline when memory is tested explicitly using tests that directly require participants to recall past events (Geraci & Barnhardt, 2010). Healthy older adults typically perform more poorly than their younger counterparts on explicit memory tasks. Such tasks require participants to remember and recall information given to them throughout the task (Ward, Berry & Shanks, 2013). For example, in a recognition task, participants are asked to remember words or pictures and then required to recall or discriminate between previously studied and new items (Ward et al., 2013).

With the clear decline of explicit memory in older adults, research has begun to look at whether implicit memory also declines with age. As discussed in Chapter 2, previous research has shown inconclusive results when looking at the decline in implicit memory in older adults, with research mostly focusing on either priming or procedural learning methodology only. Unlike explicit memory, implicit memory is tested through increased accuracy to the retrieval of information in the testing phase of the task as a result of prior exposure to the same information in the exposure phase of the task (Fleischman et al., 2004).

There is an increasing interest in the identification of lifestyle activities that can enhance cognitive ability in older adults. Participation in physical and leisure activity has been shown to have beneficial effects on cognition in advanced ageing (Kramer & Erickson, 2007). However, research into these benefits has not established whether these activities are preventing cognitive decline or are simply cognitively stimulating activities (Sturman et al., 2005, Hanna-Pladdy & McKay, 2011). Despite the understanding that physical activity has an effect on brain function, it is unclear how much of the cognitive benefit experienced by taking part in physical activity is because of the specific activity or whether there are other lifestyle factors (for example social interaction) that are necessary for the prevention of age related cognitive decline (Hanna-Pladdy & McKay, 2011).

Musical leisure activities such as playing an instrument, listening to music and creating music stimulate a wide range of cognitive functions, and may be important in the prevention of cognitive decline (Hanna-Pladdy & McKay, 2011). Hanna- Pladdy and McKay (2011), evaluated the association between musical instrumental participation and cognitive ageing. Results found that participants with at least 10 years of musical participation performed better on non-verbal memory tasks, naming tasks and executive processes compared to non-musicians, suggesting that high musical activity throughout the lifespan has a preservative effect on cognitive functioning in older adults (Hanna-Pladdy & McKay, 2011). The areas in which musicians outperformed non-musicians (memory, naming and executive functioning) are also viewed as the possible signs in the development of diagnosing neurodegenerative diseases such as dementia (Hanna-Pladdy & Mckay, 2011).

6.1.1 Aims of the study

The aim of this study was to look at the how musical training could benefit implicit memory of older adults. Previous chapters have solely focused on the difference between musicians and non-musicians. As discussed above, lifestyle choices and activity lifestyles in older adults can have a positive or negative effect on a person’s health and wellbeing. To ensure that any differences found between musicians and non-musicians are not simply due to differences in general activity levels, the current study recruited a group of older adults that live an active lifestyle but are not involved in musical activity. Three groups were therefore recruited to the study, matched approximately for age: Musicians, Active Non-musicians and Less Active Non-musicians.

6.2 Method

The present study consisted of three implicit memory tasks: Adapted Phoneme Monitoring Task, Serial Reaction Time Task and the Word Completion Task. Ethical approval was gained from the University of Chester. As all tasks were looking at implicit memory, at the time of testing participants were not aware that they were completing memory tasks. The APMT was described to participants as a listening task. They were not aware of the nature of the task until they had completed the implicit section of the task. Participants were told that they had taken part in a memory task before the explicit memory section. This procedure also applied to the SRTT task. However, this task was described as a reaction task. The Word Completion Task was described as a reading task. Participants were not aware that the words they were reading on the screen at the beginning of testing were related to the fragmented words they were required to complete in the final section of the study. Participants were given a full debrief at the end of the study that explained in full, the nature of the study.

6.2.1 Participants

Sixty-three adults (21 male and 42 female) mean age = 72.6 years participated in the experiment: 23 musicians (9 male and 14 female), 19 active non-musicians (4 male and 15 female) and 21 less active non-musicians (8 Male and 13 female). All musicians were active performers and members of local Sheffield music groups or members of the Silver Music programme at The Sage, Newcastle. All musicians had been performers throughout their life with a mean duration of 56.08 years of musical experience (calculated by participants for the number of years that they were active performers). All active non-musicians were active for more than 10hrs per week. Participants were considered active if they took part in groups outside of the home. These included both physical and mental activities. Active non-musicians were all members of groups including the University of the Third Age, community groups (politics and church groups) and members of Age UK and took part in group activities such as walking, charity fundraising, over 70's exercise clubs, information technology groups and the Age UK befriending service. Less active non-musicians took part in less than 5 hours of activity per week. Participants were recruited from retirement homes and sheltered accommodation. Less active participants did not take part in any social groups. All participants were matched for age and education. Before completing any tasks, the Mini Mental State examination (MMSE; Folstein, Folstein & McHugh, 1975) was completed by all participants as a screening tool for detection of moderate or severe cognitive deficits. The MMSE is a standardised test that is widely used as a quick screening tool for cognitive impairment. The maximum score a participant can achieve is 30 points. Scores between 24 and 30 showed no cognitive impairment, with scores below 24 suggesting cognitive impairment. Musicians and active non-musicians all scored between 26 and 29 where less active non-musicians scored between 25 and 28. No participants showed cognitive impairment, and all therefore continued to complete the study. Table 6.1 shows the demographic details for all groups.

Table 6.1. Demographic details for musicians, active and less active non-musicians.

Characteristics	Musician	Active Non-musician	Less active non-musician
Participants (N)	23	19	21
Male (N)	9	4	8
Female (N)	14	15	13
Age (Years)			
Mean	72.78	71.89	72.9
SD	5.60	4.90	5.41
Years of Musical training			
Mean	48.26	0	0
SD	14.71	0	0
Hours of activity participation			
Mean	10.78	14.16	0.88
SD	8.84	3.26	1.47

6.2.2 Adapted Phoneme Monitoring Task

Procedure and materials

Participants were asked to listen to a seven-chord sung sequence and decide as quickly as possible whether the final chord ended on the syllable /du/ or /di/. Each sequence consisted of seven chords, with each chord represented by a sung syllable. The task used in this study was the same task as used in Chapter 5 and used the same procedure (see appendix 2 for examples of sequences).

Forty-five seven-chord sequences were developed using Sibelius 6 and recorded using the sample voice sounds on the Vocal Writer singing software, version 2.0 (Cecys, 1998). This software allows for different syllables to be assigned to each chord and the four notes of a chord to be sung on the same syllable at the same time. The same eight syllables reported in Chapter 3 were used. Six syllables were the same for every sequence and the final target chord interchanged between the syllable */di/* or */du/*. The sequences were then transferred to MP3 files and the experiment was conducted using e-Prime 2.0 software. The tempo of the sequences was 96 crochet beats per minute. Participants used keys ‘A’ for */du/* and ‘L’ for */di/* on the computer keyboard to respond to all sequences. The experiment only moved on to the next sequence once the participant had pressed a response key. 3 seconds of white noise was played in between each sequence and a beep was heard to signify the start of the next sequence. The sequences were counterbalanced across participants, so that the first participant would hear the sequence with the ending */du/* and the second participant would hear the same sequence with the ending */di/*. The final block tested for explicit memory and consisted of 12 sequences in total (12 repeated sequences heard in Blocks 1-5). All sequences were missing the final target chord. Participants were asked to ‘guess’ whether the sequence would finish either the syllable */di/* or */du/* and give a confidence rating, 1=not confident to 4=confident, on how confident they were of their answer. Here we assumed that if participants had explicit memory for the previously presented stimuli, they would be likely to perform at a level above chance on the previously heard sequences, but at chance on those they had not previously encountered.

Analysis

The measures collected for the APMT were reaction time and accuracy. Median reaction time was calculated for each block and each cadence type within the block. Only correct trials were used in the analysis of the reaction time data. Mean accuracy was collected for the explicit memory blocks. A mixed 6x2x3 ANOVA was used to ascertain the effects of the repeated measures (Block: One, two, three, four, five, six; Sequence ending: Cadence, non-cadence), and group (Musicians, active non-musicians and less active non-musicians) as the between subject's variable. In the explicit memory condition, a one sample *t*-test was used to compare participants' performance to a chance rating of 50%. A Pearson's correlation was used to look at the correlation between the participant's answer and confidence ratings for their answer.

6.2.3 Serial Reaction Time Task

Procedure and materials

Participants were asked to look at four squares shown on a computer screen. Inside one of the squares a visual cue appeared (see figure 6.1). Using the F, G, H and J keys allocated on the keyboard, participants were asked to press the key that corresponds to the position of the visual cue. Participants responded bi-manually using their first and index finger of both hands to react to the visual cue (see figure 6.1)

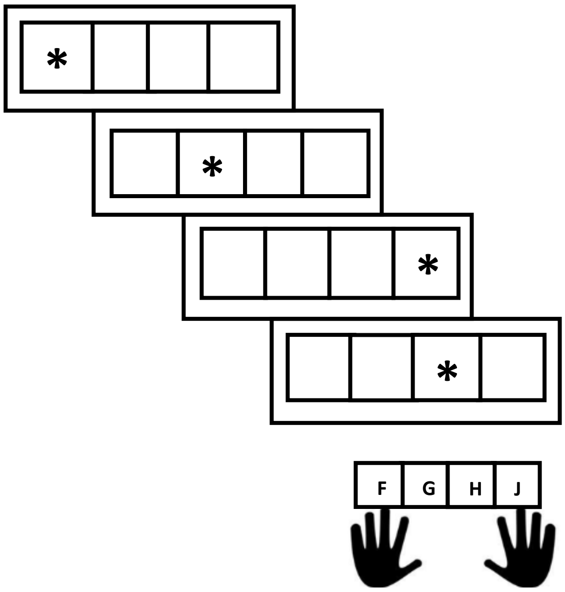

Figure 6.1. Example of a section of the Serial Reaction Time Task

Before the task began participants were given a practice block that consisted of 20 trials. In total, the task was completed over six blocks with reaction times and errors made (incorrect response for the visual cue) recorded for each response. The first block introduced the task with a random block of 80 trials. The trials did not form a sequence. Participants were asked to respond as quickly as possible to the position of the visual cue by pressing the corresponding key. A short break of 20 seconds was given to the participant in between each block. The start of the next block was indicated with a beep. Block 2 consisted of 80 trials in total. However, in this block a pattern of eight trials was repeated ten times. Designating the sequence as 1,2,3 and 4 from left to right the sequence used was 1-2-4-3-4-2-1-3. Blocks three – five were a repeat of block two. Block six contained 80 random trials that were different to all other blocks previously seen and did not form a sequence.

The final section of the task tested for explicit memory to ascertain that any learning effects found were purely due to the implicit knowledge gained throughout the task. Here, participants were told about the repeated sequence. Firstly, participants were asked to replicate the repeated sequence they had seen in Blocks 2-5 by using the allocated keys to generate the sequence they could remember. Following this, participants were asked to create a random eight trial sequence. Here we assumed that if participants could not remember the repeated sequence but replicated the sequence or part of the sequence in the random trials then we can confirm that they have not explicitly remembered the sequence shown throughout the task due to the sequence being formed randomly.

The experiment was created and run using e-Prime 2.0 software. Participants used the ‘F, G, H, J’ keys on the computer keyboard (these keys were covered by coloured stickers) to respond to the visual cue on the screen. After each response there was a 500m/s inter-stimulus interval before the next visual cue appeared.

Analysis

The measures collected for the SRTT were reaction time and accuracy (correct response to the visual stimuli). A median reaction time was calculated for each block. Only correct trials were used in the analysis of the reaction time data. A mixed 6x3 ANOVA was used to compare repeated variables (Block: One, two, three, four, five, six), with group (Musicians, active non-musicians and less active non-musicians) as the between subject variable. In the explicit memory condition, mean accuracy was collected (the amount of correct positions remembered for the repeated sequence). A one-way *t*-test was used to compare the correct positioning of the stimulus compared to a chance rating of 25%. A Chi-squared test was also used to examine the association between Group (musicians, active non-musicians and less active non-musicians) and whether participants showed any signs of explicit recall.

6.2.4 Word Completion Task

Procedure and materials

Participants were told that they were taking part in a reading task. They were asked to read 50 words aloud that were shown on a computer screen. A single word appeared on the screen and, once read, participants were able to change the word by pressing the space bar on the computer keyboard. The words were unrelated and did not form a sentence. Participants were not asked to explicitly remember any of the words on the screen. After completing all other tasks, participants were given a list of 50 words all containing missing letters. Half of the words on the list had been previously read aloud by the participants, whilst the remaining 25 were novel words that had not been seen previously. On paper, participants were asked to fill in as many of the missing words as possible.

Analysis

A two-way mixed ANOVA was used to look at the effect of group (musician, active non-musicians and less active non-musician) on the number of previously seen and novel words recalled.

6.3 Results

6.3.1 Adapted Phoneme Monitoring task

A mixed analysis of variance (Block: Block 1-6, Sequence: Cadence, Non-cadence and Group: Musicians, Active non-musicians and Less active non-musicians) was conducted. For each participant a median reaction time was recorded for each block of trials. Any incorrect answers were not included in the averages leaving an error rate of <5%. Reaction times were recorded from the start of the final chord (chord 7). Data was removed for one musician participant, due to explicitly remembering the order of the final chord for each sequence within a block. The participant sang along to the final */du/* or */di/* and in doing so formed an explicit memory for the order of the final chords. This meant that the participant was able to react to the final chord of each sequence before it was sung and explicitly recognised when the sequences changed in the final block. Tests of normality showed that the data was normally distributed. The mean reaction times for each group and Block are shown in Table 6.2.

Table 6.2. Mean reaction times for responses to musical sequences in m/s

			Group			
			Musician	Active non-musician	Less active non-musician	Total
Time of Hearing	Block 1	Cadence	1140.261 (335.489)	1154.447 (481.958)	1191.405 (248.304)	1161.587 (357.420)
		Non-cadence	1216.326 (421.853)	1223.553 (519.857)	1152.833 (231.482)	1197.341 (399.884)
		Total	1150.347 (345.045)	1188.762 (477.394)	1179.690 (246.342)	
	Block 2	Cadence	919.609 (285.311)	929.079 (441.076)	1004.500 (302.515)	950.762 (341.130)
		Non-cadence	1050.239 (515.140)	978.079 (441.079)	1040.548 (293.425)	1025.222 (438.611
		Total	946.000 (338.799)	936.026 (438.074)	1023.881 (281.361)	
	Block 3	Cadence	833.326 (379.106)	843.132 (384.495)	829.143 (279.214)	834.889 (345.108)
		Non-cadence	871.196 (398.299)	909.000 (421.448)	867.881 (286.245)	881.492 (366.911)
		Total	839.283 (374.931)	874.579 (389.743)	853.524 (280.939)	
	Block 4	Cadence	761.478 (350.402)	831.211 (407.938)	778.143 (256.999)	788.064 (337.718)
		Non-cadence	770.304 (359.137)	838.553 (405.549)	794.714 (281.795)	799.024 (346.299)
		Total	752.304 (349.616)	834.790 (397.793)	784.357 (263.642)	
	Block 5	Cadence	713.935 (332.006)	811.421 (367.003)	758.524 (306.528)	758.198 (331.846)
		Non-cadence	736.391 (366.587)	860.342 (425.808)	730.191 (234.233)	771.706 (348.535)
		Total	717.391 (335.145)	827.184 (405.576)	739.048 (270.032)	
	Block 6	Cadence	855.935 (320.532)	890.421 (410.870)	901.095 (316.008)	881.389 (343.624)
		Non-cadence	848.065 (319.244)	920.947 (399.563)	943.429 (276.217)	901.500 (329.952)
		Total	847.804 (321.151)	899.891 (396.260)	933.024 (295.493)	

A three way (Block, cadence and group) mixed ANOVA with a Greenhouse-Geisser correction showed a significant effect of Block ($F(2,156) = 63.530$, $p < .001$, $\eta p^2 = .514$). Participants continued to show quicker reaction times throughout Blocks 1 – 5, whilst showing slower reaction times to Block 6 (see figure 6.2). Post hoc tests using Bonferroni corrections revealed that across the groups participants' reaction times got faster between the first novel block (Block 1) and the final novel (Block 6)($p < .001$), showing a practice effect across the task. Participants also showed a significant increase in reaction times between Block 5 and Block 6 (252.985m/s, $p < .001$), suggesting implicit learning for sequences across participants (shown in figure 6.2). There was a significant effect of sequence ending ($F(1,60) = 10.791$, $p = .002$, $\eta p^2 = .152$). Overall, participants reacted quicker to the sequences with a cadence ending than to those with a non-cadence ending. There was no significant group effect overall ($F(2,60) = .077$, $p = .926$, $\eta p^2 = .003$).

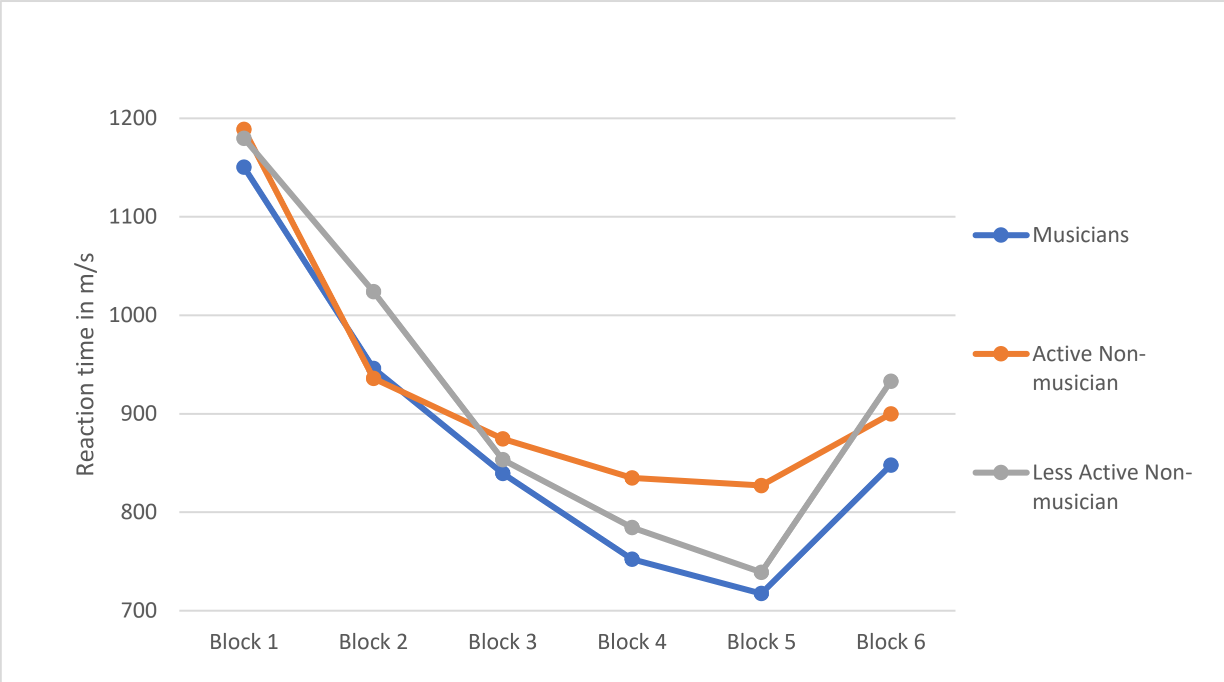

Figure 6.2. Means reaction times (in m/s) for sequences heard in each block for each group.

There were no significant two-way interactions between: block and group (F(5, 156) = .936, p = .462, ηp^2 = .030); Cadence and group (F(2,60) = 1.239, p = .300, ηp^2 = .039) and Block and Cadence (F(4,222) = 1.576, p = .186, ηp^2 = .026), nor a significant three-way interaction between Block, Cadence and group (F(7,222) = 1.386, p = .209, ηp^2 = .044).

Explicit memory

Table 6.3. Accuracy percentages and confidence ratings for explicit memory task

	Group			
	Musician	Active Non-musician	Less active non-musicians	Sub total
Accuracy	32%	32%	34%	33%
Confidence	1.89	2.33	1.42	1.87

In the explicit memory task participants were asked to 'guess' whether the final syllable ended on /di/ or /du/. A one sample *t*-test was used to look at whether participants showed any explicit memory for the repeated musical sequences by comparing their responses to chance (a 50% accuracy for the choice of /*du*/ or /*di*/). This was analysed using data from the seventh block by looking at accuracy for chord sequences that were repeated in Blocks 2-5. Accuracy scores showed that participants were performing below chance even after hearing the sequences more than once (M=32.8%, SD=.084) ($t(63) = 16.213$, $p < .001$).

A Pearson's correlation coefficient was conducted and confirmed that there was no correlation between accuracy of response and confidence ratings ($r = .081$, $n = 63$, $p = .526$).

7.3.2 Serial Reaction time task

A repeated measures analysis of variance was conducted for Block of sequences (Block 1-6) by Group (Musicians, active non-musicians and less active non-musicians). For each participant a median reaction time was recorded for each block of trials. The means for each group are shown in Table 6.4. Any incorrect answers were not included in the averages: the error rate was <5%.

Table 6.4. Mean reaction times for sequence responses in each block in m/s

		Group			
		Musicians	Active non-musicians	Less active non-musicians	Mean
Block of sequences	Block 1	574.09 (143.10)	643.53 (157.45)	766.31 (144.80)	659.10 (166.93)
	Block 2	529.91 (137.80)	596.16 (173.67)	686.81 (135.03)	602.19 (160.47)
	Block 3	464.61 (148.74)	578.08 (182.50)	610.07 (128.43)	547.32 (179.28)
	Block 4	430.24 (169.13)	566.58 (199.52)	587.52 (127.60)	523.79 (179.28)
	Block 5	395.59 (183.83)	547.16 (195.06)	492.14 (84.03)	473.48 (171.31)
	Block 6	496.26 (130.90)	604.32 (172.52)	617.79 (114.67)	569.72 (148.52)

A repeated measures analysis of variance with a Greenhouse-Geisser correction showed a significant effect of Block ($F(3, 192) = 54.885$, $p < .001$, $\eta p^2 = .478$). Participants continued to get faster throughout Block 1-5, whist Block 6 showed slower reaction times. Post Hoc test using Bonferroni corrects showed that participants reacted faster for the novel sequences heard in Block 6 compared to the novel sequences heard in Block 1 (p < .001). Participants showed a significant difference in reaction times between sequences seen in Block 5 compared to the sequences in Block 6 (p < .001) showing implicit learning for repeated sequences.

There was a significant effect of group ($F(2,60) = 6.322$, $p = .003$, $\eta p^2 = .174$) with musicians reacting faster overall. Tukey post hoc tests revealed that musicians were significantly faster, overall, than active non-musicians (107.353m/s, $p = .043$) and less active non-musicians (144.825m/s, p=.003). There was no significant difference between active non-musicians and less active non-musicians ($p = .678$).

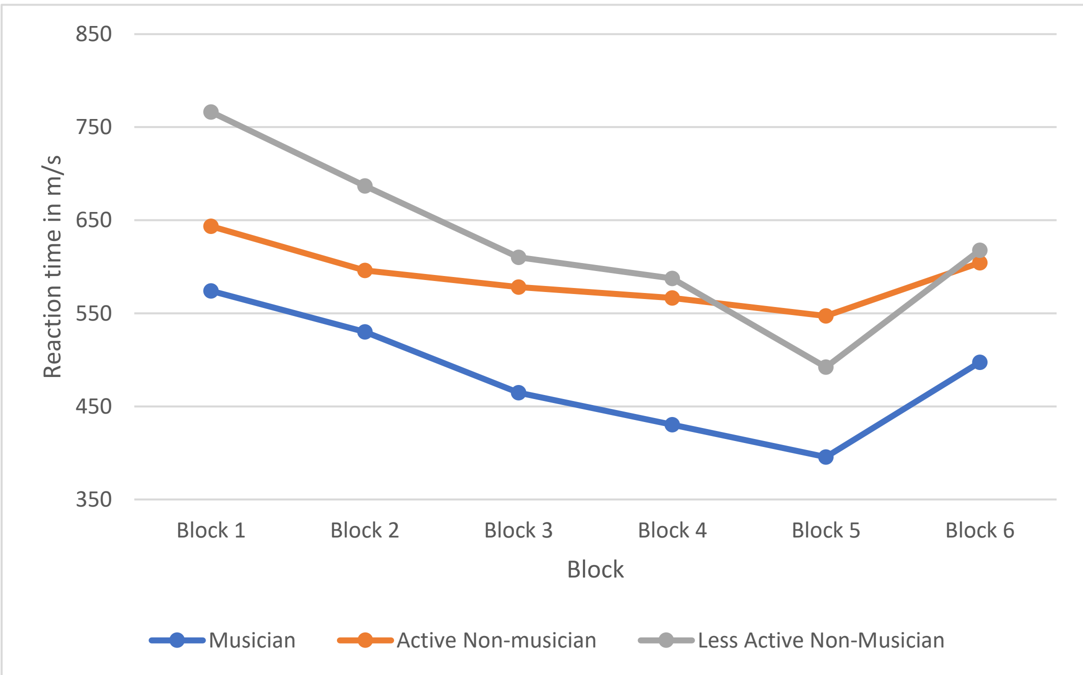

Figure 6.3. Mean reaction times (in m/s) for groups and block in the Serial Reaction Time Task.

There was a significant two-way interaction of group and block ($F(6,192) = 4.546$, $p < .001$, $\eta p^2 = .132$). When the results were partitioned by group, Bonferroni corrected post hoc tests showed a significant difference in novel sequences heard in Block 1 compared to Block 6 in Musicians (76.826m/s, $p = .032$) and less active non-musicians (148.524m/s, $p < .001$) showing a practice effect throughout the task. A significant difference between reaction times in Block 5 and Block 6 was also shown in musicians (101.674m/s, $p = .002$) and less active non-musicians (125.643m/s, $p < .001$) suggesting implicit learning in both groups. There was no significant difference found in active non-musicians between reaction times in Block 5 and 6 ($p = .193$).

Explicit memory

Participants were told that an eight-figure repeated sequence had occurred within Blocks 2-5. Firstly, participants were asked to replicate the hidden sequence. They were then asked to create a random eight figure sequence. A one sample t-test was used to look at whether participants showed any explicit memory for the repeated sequences by comparing their responses to chance (a 25% accuracy of the choice of sequence position for any given stimulus). This was analysed using data from the seventh and eighth block by looking at accuracy for sequences that were repeated in blocks two to five. Table 6.5 shows the accuracy percentage for correct positions.

Table 6.5. Accuracy percentage for correct sequence positions

	Accuracy
Replicated sequence	25.6%
Random sequence	24.4%

Accuracy scores showed that participants were performing at chance with no significant scores for sequences that were remembered (M = 25.6%, SD = .179) ($t(62) = .279$, $p = .781$) and random produced sequence (M = 24.4%, SD = .136) ($t(62) = -.342$, $p = .734$).

A Chi-Squared test was calculated looking at the association between group (musicians, active non-musicians and less active non-musicians) and whether any participants showed and explicit recall. Results revealed no association between group (musicians, active non-musicians and less active non-musicians) and explicitly remembered sequences ($\chi^2(2) = 3.024$, $p = .252$).

Table 6.6. Expected frequencies for participants performing above and below the expected 25% accuracy rate.

	Above 25%	**Below 25%**
Musician	7.3	15.7
Active non-musician	6.0	13.0
Less active non-musicians	6.7	14.3

6.3.3 Word Completion Task

A mixed analysis of variance was conducted for Words completed (primed words, novel words) by Group (Musicians, active non-musicians and less active non-musician). For each participant the number of correct answers was recorded. The mean number of correct answers for each group was recorded in table 6.7.

Table 6.7. Mean number of correct answers for words previously seen and words never seen

		Group			
		Musician	Active non-musician	Less active non-musician	Total
Words completed	Previously seen	11.78 (3.30)	10.42 (4.41)	10.19 (4.26)	10.84 (3.99)
	Never Seen	8.96 (2.55)	8.95 (2.09)	7.95 (1.83)	8.62 (2.21)
	Total	10.37 (2.93)	9.68 (3.25)	9.07 (3.05)	

There was a significant effect for type of words completed ($F(1,60) = 19.148$, $p < .001$, $\eta p^2 = .242$). Participants answered more words that had been previously seen than novel words. There was no significant group effect ($F(2,60) = 1.433$, $p = .247$, $\eta p^2 = .046$).

There was no significant interaction effect between type of words completed and group ($F(2,60) = .613$, $p = .545$, $\eta p^2 = .020$).

6.4 Discussion

The aim of this study was to look at possible implicit memory and learning differences between musicians and non-musicians on three implicit tasks: APMT, SRTT and a Word Completion Task. An important finding was that overall musicians were faster than both the active non-musicians and less active non-musicians on the APMT and the SRTT, though this did not reach significance on the APMT. Less active non-musicians were slower in both reaction time tasks but showed a similar amount of implicit learning as musicians. As in the previous studies with younger participants, participants reacted faster to the cadence ending than the non-cadence ending on the APMT showing an overall implicit preference for the common western harmony ending. In both the serial reaction time task and the adapted phoneme monitoring task, participants took part in explicit memory tasks to look at their conscious awareness for the repeated sequences. It can be concluded that participants did not show any explicit awareness for the repeated sequences as results showed participants performing at chance (c. 50% accuracy on the adapted phoneme monitoring task and c.25% on the serial reaction time task).

Implicit learning occurred in the SRTT when participants became faster at responding to the repeated sequence followed by increased reaction time when the sequence is removed; this is a pattern found in previous studies (Howard Jr. & Howard, 2013). Musicians were significantly faster than non-musicians throughout the task. A key component of both the SRTT and musical training is the ability to have precise timing. Musicians rely on precise timings and are especially skilled in discrete rhythmic actions that adhere to strict timed events, for example understanding the tempo of the music and the rhythmic pulse (Braun Janzen, Forde

Thompson, Ammirante & Ranvaud, 2014). Previous research shows that musicians perform better in fine-motor tasks than non-musicians (Kincaid, Duncan & Scott, 2002). It has been shown that musicians have a better internal timing mechanism. This suggests that performance on tasks that have the same inter-stimulus interval (for example the SRTT) musicians are able to accurately time and respond to the next visual cue (Rammsayer, Buttkus & Altenmuller, 2012). This better performance can be explained by the transfer of one learned motor skill to another motor task. The transfer of motor skills occurs when the practice and learning of one motor task (musical training) influences the performance on future tasks (Kincaid, et al., 2002). The production (including instrumental finger movements) and performing of music requires attention to timing, as does the reaction to stimuli in a SRTT (Kincaid, et al., 2002). This suggests that the transfer of motor skills from musical training to the sequencing learning task may have helped musicians react faster for the computerised stimuli. As well as a transfer effect, previous research has looked at tempo accuracy and motor timing difference between musicians and non-musicians. Motor timing has been found to have an effect on temporal prediction (Manning, Harris & Schutz, 2017) with many studies using finger tapping tasks to look at the differences between musicians and non-musicians. Previous research has shown that musicians with high levels of musical training show more accurate motor timing on tempi tasks than those with little or no musical expertise (Repp and Doggett, 2007). The finger tapping task require participants to tap along to a sequence. Within the sequence a tone would sound, and the participant would have to decide whether the tone was on-time with the sequence or out of time with the sequence. Manning et al., (2017), looked at the differences between musicians and non-musicians on the finger tapping task and found that musicians showed high synchronisation for tapping along with correct judgement for on and out of time tones. These findings suggest that temporal prediction is highly affected by musical training (Manning et al., 2017). The accuracy found in musicians in the finger tapping task helps explain the quicker reaction times shown in the serial reaction time task as musicians were able to accurately predict the timing of the next stimuli (Manning et al., 2017). It is difficult to distinguish whether musical training has had a direct effect on improvements in motor skills in musicians or whether it is the explicit training and continuous practise of motor movements that has shown a beneficial factor. Further research is needed to understand the possible benefit of musical training on motor abilities. If musical training does positively enhance motor ability, what is the effect on musician's health and wellbeing, and can these effects be shown in short term musical training in elderly non-musicians?

On the Word Completion Task, all participants answered more previously studied words correctly than novel words. Although musicians answered more words correctly than both the active and less active non-musicians this result was not significant and therefore did not show better priming for words in musicians compared other groups. Compared to the other implicit tasks used in the study, the Word Completion Task is primarily a priming task. As discussed in previous chapters, implicit memory can be split into multiple memory systems (Ullman, 2004). Procedural learning is one type of implicit memory and focuses on the learning of new and controlling of existing sensori-motor, cognitive skills and procedures for example, riding a bicycle (Ullman, 2004). This process is shown to be highly important for learning and processing sequences as it requires gradual learning after multiple exposure to the stimulus (Ullman, 2004). In the current study the SRTT and the APMT may both tap into procedural learning. The second type of implicit memory is priming. Priming can be described as an effect where exposure to a stimulus in the learning phase of the task can later influence the response to a stimulus in the testing phase of a task (Soler, Dasi & Ruiz, 2015). The Word Completion task relies on participants to unconsciously retrieve information that has previously been seen in order to complete the word fragments (Soler, Dasi & Ruiz, 2015). Previous research has argued that procedural memory and priming are separate systems within implicit memory (Gupta & Cohen, 2002). The current study supports this finding, as results suggest that musicians do not show a preservation for implicit memory in older age but actually show a preserved procedural memory as all participants performed equally on the priming task but not on the reaction time tasks.

Musicians have performed better than non-musicians on tasks that involve procedural learning than task that use priming techniques. In the present study, the SRTT is the only procedural learning task. Musicians were significantly faster than both groups of non-musicians. Musical training requires precise execution of finite motor movements (Altenmueller & McPherson, 2007). These motor movements require many hours of practice and countless repetitions in order for a musician to perform at a professional level (Altenmueller & McPherson, 2007). As well as precise motor skill, music performance relies on auditory feedback to improve and perfect musical skill (Altenmueller & McPherson, 2007). Musicians have been shown to have better procedural learning than non-musicians, which is possibly due to the advanced practice in motor and auditory skills required to become a musician. This is shown within this chapter. As well as performing faster on the SRTT, musicians also show faster reaction times overall, on the APMT. However, these results are not significant and the difference in reaction times could be due to advanced experience in auditory skills. The results shown in the APMT question the type of implicit memory that is used to complete the task. Unlike the SRTT, the APMT uses both procedural learning and priming for musical sequences. Although the same 12 musical sequences are heard in Blocks 1-5, they are only heard once within each block. The lack of repetitions could suggest that task is showing priming for musical sequences rather than procedural learning. This finding along with the results shown in the Word Completion task support the idea that musical training benefits procedural learning but doesn’t affect priming.

One of the most common forms of cognitive decline in ageing is the reduction in processing speed (the speed at which cognitive processes can be executed) and memory decline (Ward & Shanks, 2018). It is well documented and understood that explicit memory declines with age. However, the preservation of implicit memory could have many practical implications (Ward & Shanks, 2018). Many older adults are impaired in the ability to explicitly learn and recall links between individual units of information, which in turn impacts real life demand (Ward & Shanks, 2018). For example, many older adults are unable to form new pairings such as face-name pairs or learning new routines (Ward & Shanks, 2018). The ability to use implicit strategies for a range of tasks may provide a health benefit to everyday living, given that older adults may be able to successfully bring together individual pieces of information and use these associations to enhance memory (Ward et al., 2013; Ward & Shanks, 2018).

If implicit memory is preserved in healthy ageing and could provide better living for older adults, future research needs to understand whether this preservation is only present in healthy older adults or whether this is beneficial to patients with Dementia and mild cognitive impairment. As musical training has shown to preserve cognitive speed in older adults, an understanding into the preservation of implicit memory in musicians with dementia could provide possible health benefits such as performing daily activities or learning medication routines. The following chapter will aim to look at the benefits of musical training on implicit memory in older adults with dementia to understand whether implicit memory is preserved in those with cognitive impairments and whether musical training does show a beneficial effect over non-musicians.

Chapter 7

Possible benefits of musical training on implicit memory in older adults diagnosed with dementia.

7.1 Introduction

Dementia is a group of progressive neurodegenerative diseases most common in elderly adults, that affect the brain, causing deficits in the ability to learn, reason and complete everyday activities (Dementia UK, 2019). The five most common types of dementia are: Alzheimer's Disease, Lewy Body Dementia, Frontotemporal Dementia, Vascular Dementia and Mixed Dementia (Dementia UK, 2019). A common impairment in dementia is the decline in explicit memory, conscious memory, that affects a person's ability to remember and form new memories (Baird & Samson, 2009). Neurologically, explicit memory retrieval occurs in the hippocampus and entorhinal cortex, which are also areas that deteriorate early in Alzheimer's Disease (Halpern & O'Connor, 2000). However, this decline is not shown in implicit memory and priming tasks, meaning that success on priming tasks is possible in dementia patients (Halpern & O'Connor, 2000).

As previously discussed in Chapter 1, individuals diagnosed with Alzheimer's Disease and Lewy Body Dementia make up over 66% of dementia patients within the UK (Prince et al., 2014), with Lewy Body Dementia being the second most common form of dementia (Tiraboschi et al., 2006). Dementia with Lewy Bodies is often referred to as the 'Lewy Body Variant of Alzheimer's Disease' (Shimomura et al., 1998). Many studies have focused on looking at the neuropsychological differences between those diagnosed with Alzheimer's Disease and individuals with

Lewy Body Dementia. Neuropsychologically, those with Lewy Body Dementia display a different pattern of cognitive decline, with worse performance scores on attentional and executive tasks than individuals with Alzheimer's Disease (Tiraboschi et al., 2006). The deterioration on clinical measures of dementia such as the Mini Mental State exam, has been found to progress faster in those with Lewy Body Dementia than those with Alzheimer's Disease (Tiraboschi et al., 2006). Apart from subtle differences, it is important to note the difficulty in recognising Lewy Body Dementia from Alzheimer's Disease (Tiraboschi et al, 2006).

As discussed in Chapter 2, the understanding of how implicit memory is affected by dementia, or more specifically Alzheimer's Disease and Lewy Body Dementia, is still very inconclusive. The area of brain damage shown in dementia patients is not uniform across all individuals. When we add to this the lack of understanding for the areas of the brain that are used during different priming tasks, it is no surprise that results on implicit memory tasks are inconclusive (Halpern & 0'Connor, 2000). However, this is not the case when focusing on the use of musical memory in dementia patients. Research examining musical memory has found that individuals with moderate to severe Alzheimer's Disease are able to learn and reproduce novel songs (Fornazzari et al., 2006) whilst recognising and responding to familiar songs on familiarity tests (Cuddy, Sikka & Vanstone, 2015). A possible explanation for the intact musical memory is that the area of brain that is associated with musical memory is generally spared in patients with Alzheimer's Disease (Simmons-Stern, Budson & Ally, 2010) and shows an overall preservation for music in both musicians and non-musicians. Therefore, when comparing music to language ability, preserved music ability becomes more apparent because of the decline in language shown in individuals with dementia (Simmon-Stern et al., 2010).

Previous studies have looked at implicit memory for music. However, they have used non-musicians with dementia as their participants and compared the results to healthy older adults. Halpern and O'Connor (2000) looked at the differences between individuals (non-musicians) with Alzheimer's Disease, and healthy older and younger adults on a recognition task. Participants were unaware that the music they listened to in the study phase of the task was later repeated in the testing phase. As this was a test of implicit memory, in the testing phase participants were asked to rate the pleasantness of each song. If participants scored the repeated songs as more pleasant than songs that they had never heard before, then it was concluded that participants were showing implicit memory (Halpern & O'Connor, 2000). Halpern and O'Connor showed that participants with Alzheimer's Disease showed no priming for the repeated songs, whereas both older and younger adults did show the mere exposure effect for the previously heard songs. They suggested that the lack of implicit memory was due to the deterioration in the auditory areas of the temporal lobe. However, Simmons-Stern and colleagues (2010) demonstrated that on a recognition task, participants with Alzheimer's Disease were able to remember song lyrics better when they were sung than when spoken, whereas healthy older adults showed no difference between the two conditions. Simmons-Stern et al. (2010) suggest that the attentional deficits shown in those with Alzheimer's Disease could account for the differences between healthy older adults and Alzheimer's patients. Music heightens arousal, therefore an upbeat, lively song (a children's song) may enhance concentration in those with attentional deficits compared to slow and sombre song (Simmons-Stern et al., 2010). Both studies focus on non-musicians only. To understand the effect that music or musical training has on implicit memory in patients with dementia, both groups need to be compared on a range of implicit memory tasks.

7.2 Aims

To create an effective memory enhancing intervention for patients with dementia, more needs to be understood about the preservation or impairment of implicit memory. As discussed in previous chapters, procedural memory or learning is a key aspect of learning to play a musical instrument (Baird & Samson, 2009). Previous chapters have looked at the differences between musicians and non-musicians on implicit memory tasks that cover the visual, language and audio domain. A literature search has found no studies to date that focus on the differences between musicians and non-musicians where all participants were diagnosed with dementia, specifically those with Alzheimer’s Disease and Lewy Body Dementia. This study aims to compare professionally trained musicians with non-musicians on different forms of implicit learning tasks to see how music affects performance of individuals with Alzheimer’s Disease and Lewy Body Dementia on separate implicit skills, whilst also providing an insight into whether musical training is associated with better implicit memory of older adults with dementia.

7.3 Further Development of the APMT

The APMT used in Chapters 5 and 6 focuses on implicit learning and memory for 12 repeated musical sequences over six blocks. In total the task took around 20 minutes to complete. As the task is a listening task, the only visual image shown on the computer screen is the response instructions (for example, A= Doo and L=Dee). It is well researched that attention is one of the first non-memory domains to be affected by dementia (Perry & Hodges, 1999). Because of this, it was decided that fewer sequences in each block would be more beneficial and reduce distraction in participants with dementia. In this study, participants heard eight sequences in each block and completed six blocks in total. The explicit memory task was also removed as it is well documented that individuals with dementia show decline in explicit memory. In total, the APMT took around 15 minutes to complete.

7.4 Method

7.4.1 Participants

Twenty-six adults (12 male and 14 female) mean age= 71.2 years old diagnosed with Dementia participated in the experiment: 13 musicians (8 male and 5 female) and 13 non-musicians (4 male and 9 female). All participants were diagnosed with the dementia: 21 participants diagnosed with Alzheimer's Disease (10 musicians and 11 non-musicians) and 5 participants diagnosed with Lewy Body Dementia (3 musicians and 2 non-musicians). All musicians were active performers and members of local music groups or solo performers. All musicians had been performers throughout their life with a mean duration of 51.92 years of musical experience.

Participants were recruited through the Join Dementia Research (JDR) database and local Sheffield dementia groups. JDR is an online self-registration service that allows individuals with memory problems to volunteer for current memory research. In order for participants to be recruited through the JDR database, a data sharing agreement was made between JDR and the University of Chester which allows all future dementia research from the University of Chester to be advertised on the JDR database. Ethical approval was granted by the University of Chester. Participants were all tested with a carer or relative present. All participants had a full medical diagnosis of dementia, this detail is provided on the participants profile on the JDR database. Diagnosis for participants that were recruited from local dementia organisations was confirmed by carers. Participants recruited through local Sheffield dementia groups were all part of a Day Group that provides craft activities for individuals diagnosed with dementia. All participants were in the early stages of dementia and scores on the MMSE ranged from 18-22.

Table 7.1. Demographic information of musicians and non-musicians.

Characteristics	Musician	Non-musician
Participants (N)	13	13
Male (N)	8	4
Female (N)	5	9
Age (Years)		
Mean	71.31	71.00
SD	4.91	4.04
Years of Musical training		
Mean	51.92	0
SD	8.16	0

7.4.2 Procedure and materials

Adapted Phoneme Monitoring Task

Participants were asked to listen to a seven-chord sung sequence and decide as quickly as possible whether the final chord ended on the syllable /du/ or /di/. Each sequence consisted of seven chords, with each chord represented by a sung syllable. Before the task began, participants had three practice sequences that gave each participant feedback whether the answer they gave was correct or not. The task was completed over six blocks in total, with reaction times and error rate recorded for the phoneme detection. The first block introduced the task. It consisted of eight sequences in total, four sequences with a cadence ending (two ending on the phoneme /di/ and two ending on /du/) and four non-cadence endings (three ending on the phoneme /di/ and three ending on /du/). Between each sequence the participant heard three seconds of white noise followed by a beep to indicate the start of the next sequence. Blocks 2 to 5 were a repeat of the sequences heard in Block 1. Block 6 contained eight novel sequences that had never been heard before.

Thirty-eight seven-chord sequences were developed using Sibelius 6 and recorded using the sample voice sounds on the Vocal Writer singing software, version 2.0 (Cecys, 1998). This software allows for different syllables to be assigned to each chord and the four notes of a chord to be sung on the same syllable at the same time. The same eight syllables heard in Chapter 4 were used. The first six syllables were the same for every sequence and the final target chord interchanged randomly between the syllable */di/* or */du/.* The sequences were then transferred to MP3 files and the experiment was run on e-Prime 2.0 software. The tempo of the sequences was 96 crochet beats per minute. Participants used a blue key (letter 'A') for */du/* and red (letter 'L') for */di/* on the computer keyboard to respond to all sequences. The experiment only moved on to the next sequence once the participant had pressed a response key. The sequences were counterbalanced across participants, so that the first participant would hear a given sequence with the ending */du/* and the second participant would hear the same sequence with the ending */di/* to control for any intrinsic differences between the sequences.

Serial Reaction Time Task

Participants were asked to look at four squares shown on a computer screen. Inside one of the squares a visual cue appeared. Using the keys allocated on the keyboard, participants were asked to press the key that corresponded to the square on the screen when the visual cue appeared. Before the task began participants were given a practice block that consisted of 20 trials. In total, the task was completed over six blocks with reaction times and error rate recorded for each response. The first block introduced the task with a random block of 80 trials. The trials did not form a sequence. Participants were asked to respond as quickly as possible to the position of the visual cue by pressing the corresponding key. A short break was given to the participant in between each block. The start of the next block was indicated with a beep. Block 2 consisted of 80 trials in total, however in this block a pattern of eight trials were repeated ten times. Designating the sequence as 1,2,3 and 4 from left to right the sequence used was 1-2-4-3-4-2-1-3. Blocks 3-5 were a repeat of Block 2. Block 6 contained 80 random trials that were different to all other blocks previously seen and did not form a sequence. The experiment was created and run using e-prime 2.0 software. There was an inter-stimulus interval of 500m/s between each stimulus. Participants used the ‘F, G, H, J’ keys on the computer keyboard (these keys were covered by coloured stickers) to respond to the visual cue on the screen. The experiment only moved on to the next visual cue when the participant had pressed a response key.

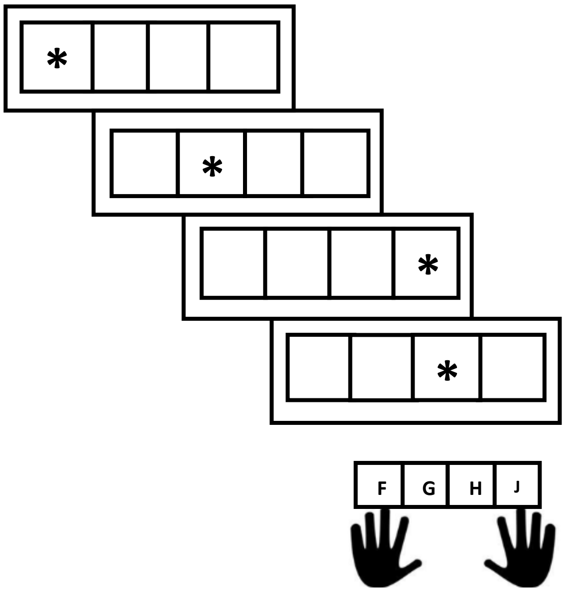

Figure 7.1 Example of a section of the Serial Reaction Time Task.

Word Completion Task

Participants were asked to read 50 words aloud that were shown on a computer screen. A single word appeared on the screen and once read participants were able to change the word by pressing the space bar on the computer keyboard. The words were unrelated and did not form a sentence. Participants were not asked to explicitly remember any of the words on the screen. After completing all other tasks participants were given a list of 50 words all containing missing letters. Twenty-five of the words on the list had been previously read aloud by the participants, whilst the remaining 25 were novel words that had not been seen previously. Participants were asked to fill in as many of the missing words as possible.

7.4.3 Analysis

The primary measures collected for both the SRTT and the APMT were reaction time and accuracy. A median reaction time was calculated for each block on both tasks to account for skew in individual data. Only correct trials were used in the analysis of the reaction time data. A mixed ANOVA was used to compare repeated factors (Block: 1-6; Sequence ending: Cadence, Non-cadence), with group (Musicians, Non-musicians) as the between subject variable. For the word completion task, a 2x2 mixed anova was used to compare musicians and non-musicians on the number of previously seen words and the number of novel words identified.

7.5 Results

7.5.1 Adapted Phoneme Monitoring task

A mixed analysis of variance was conducted using the two repeated measures variables (Block: Block 1-6 and Sequence: Cadence, Non-cadence) and group (Musicians and Non-musicians). For each participant a median reaction time was recorded for each block of trials. The means for each group is shown in Table 7.2. Reaction times were recorded from the start of the final chord (chord 7).

Table 7.2. Mean reaction times for responses to musical sequences in m/s

			Group		
			Musicians	Non-musicians	Total
Block	Block 1	Cadence	944.654 (337.155)	1245.308 (310.988)	1082.904 (346.399)
		Non-cadence	941.654 (323.102)	1255.231 (303.978)	1098.442 (346.452)
		Total	943.154 (330.129)	1250.270 (307.483)	1090.673 (346.430)
	Block 2	Cadence	750.885 (345.206)	1041.577 (284.590)	896.231 (343.928)
		Non-cadence	717.654 (344.210)	1103.115 (334.102)	910.385 (386.110)
		Total	734.270 (344.708)	1072.346 (309.346)	903.308 (365.019)
	Block 3	Cadence	651.154 (282.363)	950.731 (391.633)	787.846 (365.747)
		Non-cadence	773.385 (803.698)	894.115 (319.341)	833.750 (603.317)
		Total	712.269 (543.031)	924.808 (352.421)	810.798 (484.532)
	Block 4	Cadence	673.885 (289.144)	854.539 (379.751)	764.212 (349.004)
		Non-cadence	602.654 (283.825)	763.808 (301.830)	683.231 (298.572)
		Total	638.270 (286.485)	809.174 (340.791)	723.722 (323.788)
	Block 5	Cadence	538.462 (267.471)	748.039 (353.569)	643.250 (325.215)
		Non-cadence	578.846 (255.963)	707.539 (303.808)	643.192 (282.945)
		Total	558.654 (261.717)	727.789 (328.689)	632.390 (303.080)
	Block 6	Cadence	931.154 (229.515)	983.539 (419.565)	957.346 (329.421)
		Non-cadence	941.692 (247.364)	954.769 (351.983)	948.231 (298.133)
		Total	936.423 (238.440)	969.154 (385.774)	952.789 (313.777)

A three way (Block, sequence, and group) mixed ANOVA with a Greenhouse-Geisser correction showed a significant effect of Block (*F*(3.517, 84.416) = 22.795, *p* < .001, η_p^2= .487). Participants continued to react faster throughout Blocks 1-5 and slower in Block 6. Post hoc tests using Bonferroni corrections revealed that there was a significant difference between sequences heard in Block 5 and Block 6 with participants showing slower reaction times for the novel sequences in Block 6 compared to the final repeated sequences in Block 5 (320.399m/s, *p* < .001). Results revealed a significant effect of Group (*F*(1,24) = 4.987, *p* = .035, η_p^2 = .172). Overall, musicians reacted faster throughout all Blocks than non-musicians. There was no significant effect of sequence ending (*F*(1,24) = .047, *p* = .831, η_p^2 = .002).

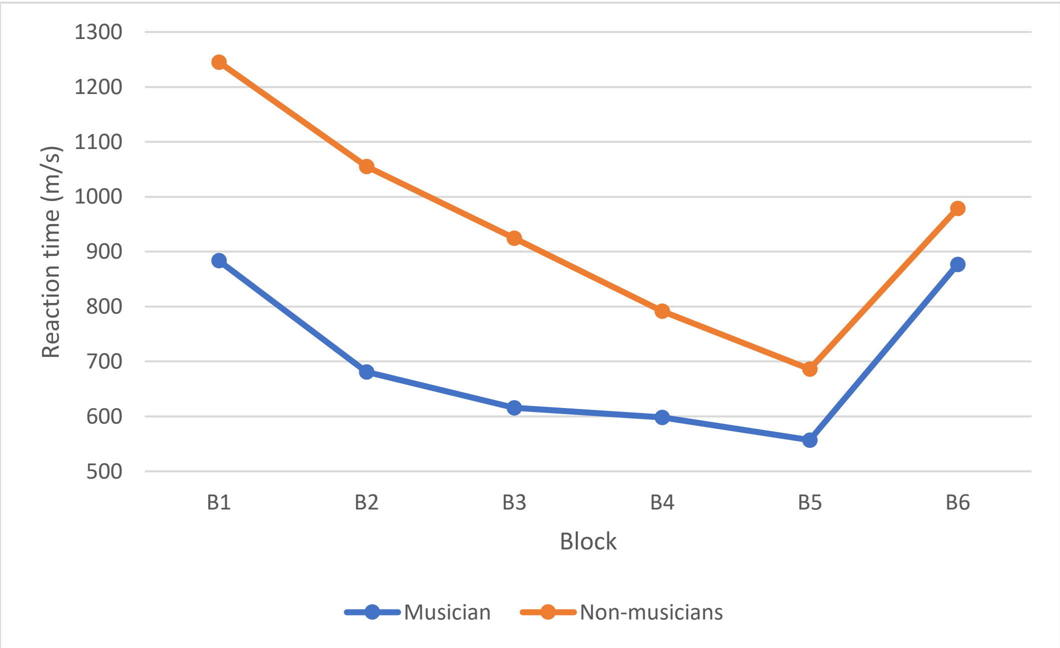

Figure 7.2. Mean reaction times for musician and non-musicians.

There was a significant two-way effect of Block and Group (*F*(3.517, 84.416) = 2.663, *p* = .045, η_p^2 = .100). Post hoc tests using Bonferroni corrections revealed that neither musicians (*p* = 1.000) nor non-musicians (*p* = .165) showed a significant difference between novel sequences heard in Block 1 and the novel sequences heard in Block 6. It would be expected that the difference in reaction times between the novel sequences heard in Block 1 and Block 6 might evidence a practice effect of the study. Results showed a significant difference in both musicians (*p* < .001) and non-musicians (*p* = .003) for the repeated sequences heard in Block 5 and the novel sequences heard in Block 6, showing clear implicit learning for the sequences. Both musicians and non-musicians showed slower reaction times for sequences heard in Block 6 compared to Block 5. There was no significant interaction between sequence ending and group (*F*(1,24) = .430, *p* = .518, η_p^2 = .018) or between Block and sequence ending (*F*(2.607,62.560) = .456, *p* = .687, η_p^2 = .019). There was no significant three-way interaction between Block, sequence ending and group (*F*(2.607, 62.560) = .635, *p* = .574, η_p^2 = .026).

7.5.2 Serial Reaction Time task

A repeated measures analysis of variance was conducted between Block of sequences (Block 1-6) and Group (Musicians and non-musicians). For each participant a median reaction time was recorded for each block of trials. The means for each group are shown in Table 7.3.

Table 7.3. Mean reaction times (m/s) for each block of sequences.

		Group		
		Musicians	Non-musicians	Total
Block	Block 1	870.08 (237.75)	1085.50 (291.08)	977.79 (282.61)
	Block 2	764.23 (216.23)	1082.96 (278.85)	923.60 (293.56)
	Block 3	687.12 (214.49)	917.39 (282.36)	802.25 (272.28)
	Block 4	585.42 (227.19)	848.39 (220.00)	716.90 (256.88)
	Block 5	503.35 (170.34)	773.12 (220.31)	638.23 (236.95)
	Block 6	738.81 (164.66)	848.46 (212.81)	793.64 (194.63)
	Total	691.50 (205.11)	925.97 (250.90)	809.74 (228.01)

A repeated measures analysis of variance showed a significant effect of Block ($F(1,24) = 21.796$, $p < .001$, $\eta_p^2 = .476$). Participants continued to get faster throughout Block 1-5, whist Block 6 showed slower reaction times. Post Hoc pairwise comparisons using a Bonferroni correction showed that participants reacted faster for the novel sequences heard in Block 6 compared to the novel sequences in Block 1 ($p = .007$). Participants showed a significant difference in reaction times between sequences seen in Block 5 compared to the sequences in Block 6 (p < .001) showing implicit learning for repeated sequences. There was a significant effect of group (F(1,24) = 9.494, p = .005, η_p^2 = .283) with musicians reacting faster overall.

Although the musicians appear to be showing greater implicit learning as shown in the slope of the line between Blocks 5 and 6, there was no significant interaction between Block and Group (F(5,120) = 1.721, p = .135, η_p^2 = .067).

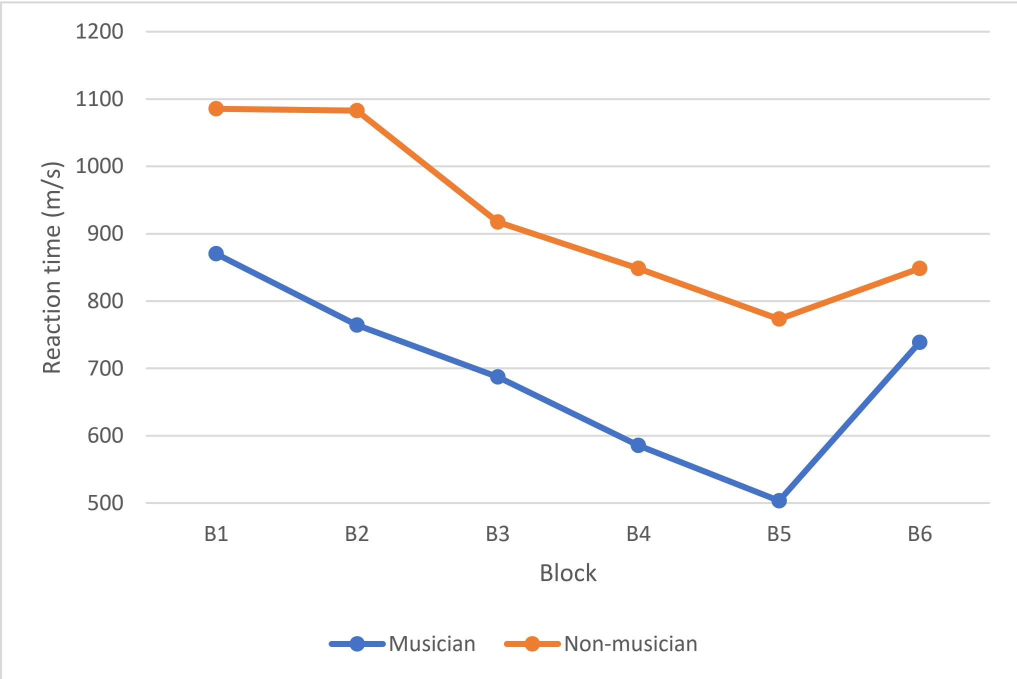

Figure 7.3. Mean reaction times (m/s) on a Serial Reaction Time Task for musicians and non-musicians

7.5.3 Word Completion Task

A repeated measures analysis of variance was conducted between Words completed (primed words, novel words) and Group (Musicians and Non-musicians). For each participant the number of valid responses were recorded. There as a total of 50 words altogether: 25 primed word and 25 novel words. The mean number of correct answers for each group was recorded in Table 7.4. Not all participants were able to write their answer on the fragment sheet but were able to vocalise the word they wanted as an answer. This occurred for eight participants in total (five non-musicians and three musicians). For these participants, the researcher filled in the words that the participants vocalised.

Table 7.4. Mean number of correct answers for words previously seen and words never seen.

		Group		
		Musician	Non-Musician	Total
Words completed	Primed words	8.77 (2.13)	8.46 (2.82)	8.62 (2.45)
	Novel words	7.08 (2.22)	7.77 (2.49)	7.42 (2.34)
	Total	7.92 (2.17)	8.12 (2.65)	8.02 (2.41)

A repeated measures analysis of variance revealed no significant effect of group ($F(1,24) = .074$, $p = .788$, $\eta_p^2 = .003$). There was no significant difference between words that had been previously seen compared to words that had not ($F(1,24) = 3.499$, $p = .0724$, $\eta_p^2 = .127$). However, despite the non-significant result, there is a trend in the expected direction for priming with participants completing more fragments with previously seen words than novel words.

There was no significant interaction between primed words and group ($F(1,24)$ = .615, p = .440, η_p^2 = .025).

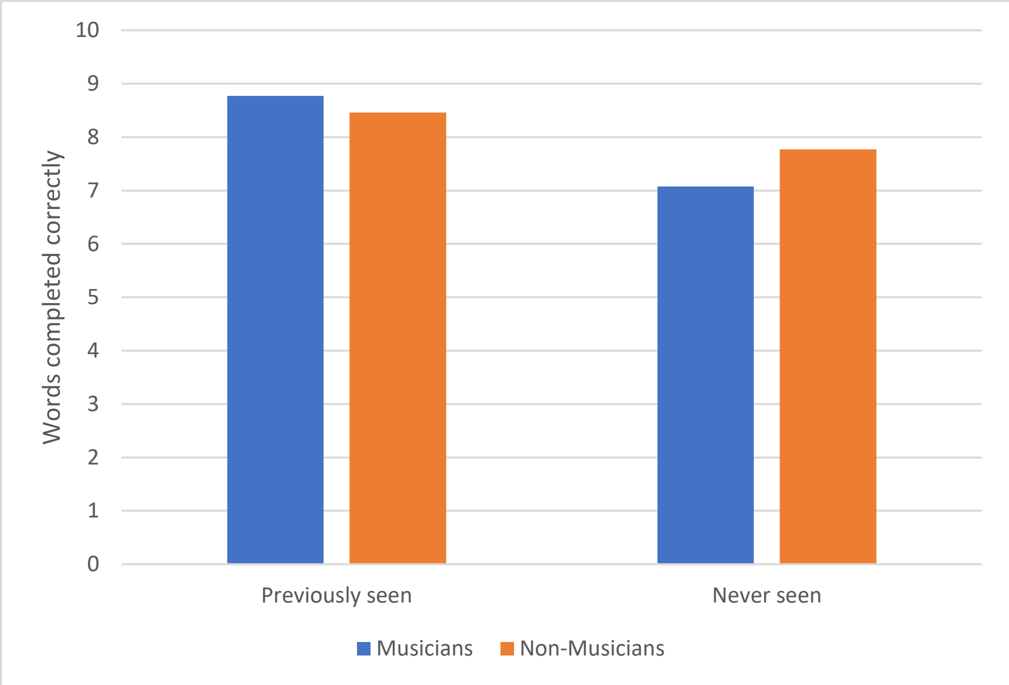

Figure 7.4. Number of words completed correctly by musicians and non-musicians

7.6 Discussion

The main goal of the present study was to investigate the possible differences on implicit memory tasks between musicians and non-musicians with dementia. The results showed that musicians performed better than non-musicians on implicit learning tasks with faster reaction times shown in both the Adapted Phoneme Monitoring Task and the Serial Reaction Time Task.

The results suggest that on the Adapted Phoneme Monitoring Task (see figure 7.2), both musicians and non-musicians displayed implicit learning as measured by the difference between the reaction times shown in Block 5 and Block 6. On the Serial Reaction Time Task both musicians and non-musicians showed an increase in reaction times for the novel stimuli shown in Block 6. However, the difference between Block 5 and 6 was greater in musicians. The fact that this did not manifest as a significant interaction may in part be due to high variability in both groups, particularly the non-musicians. The non-musician group showed higher variability in reaction times throughout both reaction tasks. The issue of high variability is one which has been noted in a number of studies (Stark-Inbar, Raza, Taylor & Ivry, 2017) and does make any difference in implicit learning in the two groups harder to distinguish.

Music is widely used as a therapeutic technique for dementia patients with research showing the possibility of music skills remaining despite cognitive skills declining (Halpern & O'Connor, 2000). A case study by Crystal, Grober and Masur (1989) found a preservation in procedural memory for music performance in a participant diagnosed with dementia. The participant was unable to recall or recognise previously learned musical compositions. However, they could perform the musical compositions on the piano after cueing (Crystal, Grober & Masur, 1989). The art of playing an instrument requires many years of practice and has been found to affect the structure and organisation of the cortex (Schlaug, 2001). This suggests that after years of musical training and education, structural changes may benefit musicians with dementia, allowing them to perform better than the average music listener on procedural tasks (Vanstone & Cuddy, 2009).

As well as showing implicit learning on sequence learning tasks, musicians also showed faster reaction times on both the Serial Reaction Time and Adapted Phoneme Monitoring tasks. Learning to play a musical instrument and read music notation involves the development of cognitive and motor skills which are likely to transfer to more general behavioural responses (Brochard, Dufour & Despres, 2004). These results support the findings by Watanabe, Savion-Lemieux & Penhune (2007), suggesting that musical practice in early childhood can enrich motor skills which result in long-lasting benefits for performance in later life. Most musical instruments require finger movement in either one or both hands, and all musical performances require precise attention to timing (Kincaid, Duncan & Scott, 2002). Franek et al. (1991) assessed the motor timing skills of musicians and non-musicians on a finger tapping task. Participants had to repeat a rhythmic tonal pattern after listening to a sequence of acoustic patterns. Franek and colleagues found that musicians were significantly more accurate in their motor timing on a variety of different time intervals (Franek et al., 1991). The transfer of the timing skills shown in music performance compared to the motor timing skills, where there is a specified interval of 500ms between the response and the appearance of the next visual cue, required on the Serial Reaction Time Task can suggest that musicians have an overall advantage at timing the ISI (Kincaid, Duncan & Scott, 2002).

Word stem completion tasks are often impaired in participants with Alzheimer's Disease (Fleischman et al., 1997). The results from this study show no difference between musicians and non-musicians, with musicians answering a similar number of words to non-musicians. There was no difference between the words that had been previously primed compared to the novel words. One explanation for the lack of implicit memory shown in the word completion task in comparison to the other tasks may be that the word priming task relies on conceptual processing with the SRTT and APMT may rely on perceptual processing

(Fleischman et al., 1997). Conceptual processing concentrates on the content or meaning of the target stimuli, in this case the primed word, whereas perceptual processing focuses on the visual or auditory form of the target stimuli (Fleischman et al., 1997). Keane et al. (1991) looked at the processing difference between the word stem completion task and a perceptual processing task in patients with Alzheimer's Disease. Results showed that priming was impaired on the word stem completion task and intact on perceptual processing tasks (Keane et al., 1991). The finding that conceptual processing may be impaired in patients with dementia is not conclusive. Fleischman et al. (1997) state that there are as many studies that show implicit learning in the word stem completion task as do not. One explanation for this could be the stage at which the failure of conceptual processing occurs. Fleischman et al. (1997) suggest that the priming deficit could reflect a failure in semantic encoding (the encoding of the meaning of the word) which is impaired in patients with Alzheimer's Disease. The current findings support previous research, as participants showed implicit learning on tasks that involved perceptual processing (SRTT and APMT) but not on tasks that involved conceptual processing (Word Completion Task)

Both musicians and non-musicians showed implicit learning on the Adapted Phoneme Monitoring Task. This indicates that both musicians and non-musicians are able to show implicit learning for musical sequences. Musicians showed faster reaction times for both sequence tasks suggesting better motor skills than non-musicians. Previous research has suggested that structural and function changes in the brain, particularly in the auditory and motor regions, (Gaser & Schlaug, 2003), due to musical training, are greater for those who began training in their childhood

(Watanabe, Savion- Lemieux & Penhune, 2007). Therefore, as previously discussed, the structural changes shown in musicians may not be affected by dementia. Further research is needed to look at how the benefits of musical training in those with dementia can be beneficial to everyday life, including the performance of everyday tasks (preparing food, getting dressed). The next chapter will draw some overall conclusions about the differences and similarities in performance on implicit memory tasks between healthy adults (Chapter 6) and the individuals with dementia (current chapter). This comparison will look at the degree to which musical training has benefitted implicit learning in individuals with dementia and whether they are performing as well as healthy older adults.

Chapter 8

General Discussion

The overall aim of this thesis was to look at the possible implicit memory differences between musicians and non-musicians on both an implicit musical memory task and general implicit memory tasks. Previous research has looked at the benefit of musical training on verbal tasks (Taylor & Dewhurst, 2017), working memory (Roden et al., 2014) and explicit memory (Baird & Samson, 2017). Literature searches did not identify any studies to date that look at the benefits of musical training on implicit memory and learning in different populations, including healthy older adults and individuals diagnosed with dementia, on different implicit memory tasks. This is where the current research aims to add to the literature.

A key aspect of the current research is the possible differences between musicians and non-musicians on both musical and general implicit memory tasks. It is important to understand the possible benefits that musical training could provide to both healthy older adults and to those diagnosed with dementia, as memory decline is a key factor of growing old. With a population of nearly 12 million people over the age of 65 living in the UK alone (Office for National Statistics, 2019) and over 50 million people living with dementia globally (World Health Organisation, 2018), it is important to form a clear understanding of ways in which creative platforms can help the ageing community.

Chapter 3 explored the current literature that looked at implicit memory and music. From this chapter it is clear that there is little research that looks at implicit music learning specifically in both musicians and non-musicians. The subsequent chapters aimed to develop an implicit musical learning task that was accessible to both musicians and non-musicians to enable an insight into the processing of musical stimuli. Chapters 4 and 5 focused on the development of the Adapted Phoneme Monitoring Task (APMT), an implicit musical memory task that looked at implicit learning and knowledge of musical sequences. Results indicated that participants showed implicit learning for musical sequences, with a significant difference found between reaction times in the final block of repeated sequences (Block 5) and the novel sequences heard in Block 6 of the APMT.

Developing an implicit musical task that was accessible to both musicians and non-musicians was key to the designing of the APMT. In Chapter 4, despite musicians performing slightly faster overall, there was no significant difference between reaction times for musicians and non-musicians. Both groups showed faster reaction times for the repeated sequences heard in Block 2. This difference in reaction time from Block 1 to Block 2 in both musicians and non-musicians demonstrated a degree of implicit memory for previously heard musical sequences. This finding, along with participants showing implicit knowledge for western harmonies (participants reacted faster for cadence chords than non-cadence chords, as in the Bigand et al. (2001) study) prompted further changes to the AMPT to look at implicit musical learning for repeated musical sequences in both musicians and non-musicians.

Typical implicit sequence learning tasks provide a measure of participants' incidental learning of both the sequence shown or heard, and the association between the sensory cue and the required response (Robertson, 2007). In order for this implicit learning to occur, a sequence is repeated multiple times throughout the task without explaining to the participant that the sequence exists (Robertson, 2007). In Chapter 5, the APMT contained six blocks in total. Each block contained 12 seven-chord sequences which meant that each sequence is heard five times during the entire task. Compared to other procedural learning tasks, for example the Serial Reaction Time Task (SRTT) where the repeated sequences occur 10 times per block, the APMT contained fewer repetitions due to the overall length of the task. By adding more sequence repetitions to the APMT, it is likely that participants would show a greater degree of procedural learning for those repeated sequences. However, adding extra sequences creates different kinds of problems. The task took around 20 minutes to complete, making the overall time it took to complete the task quite a substantial amount of time for older adults and individuals with dementia. This was mentioned by some older adults during the debrief of the study. The possibility of shortening individual musical chord sequences and therefore enabling more repetitions, could potentially allow for a stronger indication of implicit learning in individual groups. However, this could also increase the chances of explicit recognition. In order for the musical sequence to sound finished or complete, the sequence should finish on a strong beat (for example, the first beat of a musical bar structure). In the case of the APMT, sequences are in two beats per bar, meaning that the strong beat lies on the first beat of each bar (see figure 4.1). In this study, this was the 7th note of the sequence and therefore shortening this would mean that the final chord would either be heard on the 3rd note or the 5th note of the sequence. This could increase the chances of explicit recognition as participants could pick up explicitly on the repetition of musical sequences because of the short amount of time from one sequence to the next, as well as a higher possibility of remembering the shortened sequences. Looking at group data, the explicit memory test showed that all participant groups performed at chance and showed no explicit learning for the repeated sequence. The changes made to Study 2 (see Chapter 5) were able to add further support to the results of Study 1 (see Chapter 4) which showed a degree of implicit learning for musical sequences shown in both musicians and non-musicians.

Chapter 6 focused on the differences between older adult musicians and active/less active non-musicians on both the APMT and general implicit memory tasks; SRTT and Word Completion Task. The aim of the study was to look at the possible benefits of long-term musical training on implicit memory and learning. Overall, musicians showed faster reaction times on the SRTT. However, results for the separate tasks showed different advantages for musicians. Results for the SRTT showed that musicians were significantly different to non-musicians and overall, reacted faster than both active non-musicians and less active non-musicians. However, there was no group difference on the Word Completion Task. Although both tasks are implicit tasks, the SRTT is a procedural learning task and therefore focuses on motor learning whereas, the Word Completion task is an implicit learning task that uses priming techniques. The APMT, did not show any significant difference between the groups. However, it cannot be defined purely as either a procedural learning task or a priming task, as it spans both domains. The APMT as a whole, may partially test motor learning as the same sequences are repeated five times throughout the task and participants may implicitly learn a sequence of motor responses. However, participants are also experiencing priming of the musical sequence itself. This differs from the SRTT as the stimulus response association in the SRTT relies on a reaction to each stimulus shown on screen, whereas the AMPT focuses on the final phoneme only. Therefore, participants are processing multiple phonemes and chords before reacting to the final chord.

Finally, Study 4 (Chapter 7) replicated the tasks used in Study 3 (Chapter 6). The aim of the task was to look at whether the distinction between musicians' and non-musicians' procedural learning found in Study 3 (Chapter 6) continues in adults diagnosed with dementia. Musicians with dementia showed faster reaction times on both the SRTT and the APMT compared to non-musicians. These results support the concept of musicians performing better on procedural learning tasks and suggests that musical training has a protective feature in older age and in musicians with dementia on procedural tasks. Further research is needed to look into whether the preservation of musical performance, which has a high degree of procedural skill, in adults with dementia transfers into cognitive skills of everyday life, for example making a drink, or performing simple cooking tasks. If these skills do transfer, or if musicians show better preservation for daily life skills, it is possible that music training over the life span could help preserve cognitive function and therefore provide better quality of life for both healthy adults and adults with dementia.

Across the four studies, participants, both musicians and non-musicians, ranged from students to healthy older adults and older adults diagnosed with dementia. Although participants changed within each study, all participants completed the APMT, but only older adults and individuals with dementia completed the SRTT and the Word Completion Task. The consistent methodology allows for some comparisons to be made across the different age groups. Overall, in all studies, musicians appear to have an advantage on implicit tasks. However, the less procedural the task is, the less prominent this effect is.

Study 2 (Chapter 5) focused on younger adult musicians and non-musicians and found no significant group difference. Although no group difference was found, reaction times in musicians and non-musicians for novel sequences heard in Block 6 were slower than the repeated sequences heard in Block 5. This suggests that implicit learning for musical sequences was shown by both groups. It was expected that older adults would react slower than their younger counterparts on the APMT. This was the case when looking at the difference between the reaction times shown in Study 3 (Chapter 6) and those in Study 2 (Chapter 5). In Study 3 (Chapter 6), healthy older adult musicians were overall faster than healthy older adult non-musicians. However, when looking at the differences in age from younger adults in Study 2 and older adults in Study 3, older adult musicians were between 100-170m/s slower than younger musicians. The difference between younger and older adult non-musicians was bigger than that of musicians, with older adult non-musicians reacting between 180 and 340m/s slower than younger non-musicians. It was expected that if musical training benefits implicit memory then older adult musicians would react similarly to younger adult non-musicians. However, as younger adult non-musicians were faster than musicians in the initial stages of Study 2 (Chapter 5) this was not the case, and the difference between younger adult non-musicians and older adult musicians was bigger than that shown between both younger and older adult musicians.

Following the ageing trend, it was expected that musicians with dementia would perform slower than healthy older adult musicians on all reaction time tasks. However, this was not the case for the APMT. Study 4 (Chapter 7) shows that musicians with dementia performed as fast or faster than younger adult musicians with reaction times ranging between 880m/s (Block 1) and 550m/s (Block 5) for musicians with dementia and 1045m/s (Block 1) and 540m/s (Block 5) for younger adult musicians. However, it should be noted that the task was easier. Individuals with dementia heard fewer musical sequences (eight repeated sequences per block in Study 4 compared to 12 repeated sequences per block in Study 2). Yet musicians with dementia were faster in Block 1 and therefore started the task faster than younger adults. This suggests that hearing fewer sequences cannot, on its own, account for the similarity in reaction times and therefore the reason for these reaction times could be further explored in future research.

Throughout the APMT, participants were not asked to pay any explicit attention to the musical structure of the chord sequence, only the final phoneme. Just like the Bigand et al (2001) study (see Chapter 3), this allowed for the task to test for harmonic priming by using comparisons between cadence chords and non-cadence chords. Overall, in Studies 1, 2 and 3 (Chapters 4, 5 and 6), participants reacted faster for the cadence endings than the non-cadence endings. In the first study, where there was a difference between musicians and non-musicians, it is actually non-musicians that show a faster reaction to cadence endings than non-cadence endings. There is no obvious explanation for these subtle differences in reaction times between musicians and non-musicians in the first study. However, as discussed in Chapter 3, musical expertise takes years of training, which includes explicit learning of musical harmony. Due to the extensive training, it is expected that musicians would be able to easily detect a cadence ending from a non-cadence ending and could handle the unexpected ending more readily than non-musicians. However, despite the lack of musical training, non-musicians are still able to identify harmonic differences in musical sequences. This could be due to exposure to modern western music. It is suggested that non-musicians can gain implicit knowledge of harmony through mere exposure to music (Bigand & Poulin-Charronnat, 2006). Although non-musicians are not able to explicitly describe the harmonic differences heard in musical sequences, the results from the AMPT suggest implicit knowledge of musical harmony despite the lack of musical training.

Results for Study 3 and 4 (Chapters 6 and 7) further support the understanding that musical training protects procedural memory. The SRTT was used here to look at procedural learning in healthy older adults and individuals with dementia. In both studies musicians performed faster than non-musicians, with Study 3 showing a significant difference between musicians and less active non-musicians, and Study 4 showing a significant group difference between musicians and non-musicians with dementia. When comparing the reaction times of healthy older adults and individuals with dementia, it is interesting to see that musicians with dementia performed as well as less active non-musicians on the SRTT. Looking at the differences in reaction times between healthy older adults and individuals with dementia, musicians with dementia had similar reaction times to healthy less active older adults. Musicians with dementia were performing between 500m/s (Block 5) and 870 m/s (Block 1) and healthy less active non-musicians performed between 500m/s (Block 5) and 770m/s (Block 1). The difference between musicians and non-musicians on individual studies, and musicians with dementia performing as well as less active non-musicians, indicates a musical training benefit to procedural learning that is not affected by dementia but only in musicians.

Both Study 3 and 4 (Chapters 6 and 7) used the Word Completion Task. Although musicians completed slightly more previously seen words correct than non-musicians, neither study saw significant group differences. In Study 3 (Chapter 6), musicians completed an average of 12 previously seen words correctly. However, musicians with dementia showed decrements in word priming completing an average of 8 previously seen words correctly. Although musicians perform faster than non-musicians on implicit tasks in general, musical training appears to only protect procedural learning of musicians (both healthy older adults and individuals with dementia) and not priming.

8.1 Implications

The present research showed that both healthy older adult musicians and musicians with dementia performed better than their non-musician counterparts on procedural memory tasks than priming tasks. Despite this better performance it is too premature to say that musical training preserves implicit memory in musicians in later life and in those with neurological disorders. One reason for this is due to both musicians and non-musicians showing intact implicit memory throughout all studies. Despite the slower reaction times, non-musicians do show similar patterns of implicit memory to that shown in musicians. It is well understood that explicit memory declines with age and is a key predictor of dementia. Declines in prospective memory is also apparent in older adults and individuals with dementia. Prospective memory is defined as remembering to carry out intended action at some point in the future and is highly important for maintaining independent living (Van den Berg, Kant & Postma, 2012). Failing to perform future tasks, such as getting dressed independently, could have a negative impact on an individual’s life (Spindola & Brucki, 2011). Declines in prospective memory have been found to have a detrimental effect on performing activity-based tasks, for example remembering to take medication after dinner (Spindola & Brucki, 2011). Along with declines in explicit memory, declines in prospective memory could have a serious impact on the completion of everyday tasks and continuing independent living in older adults and individuals with dementia. Despite declines in both explicit and prospective memory, both healthy older adults and individuals with dementia are able to use the different parts of their implicit memory, for example, procedural learning techniques such as repetition of tasks or movements, and implicit associations, such as associating songs to places or people. The use of implicit and procedural memory could possibly help older adults’ complete everyday tasks and future challenges easier than through explicit or prospective memory techniques.

The impact of being able to use implicit learning techniques for everyday life tasks could have a beneficial effect on an individual’s health and in society. If an individual with dementia is able to gain or retain prior lifestyle knowledge by using implicit techniques, this could enable them to live a healthy life within their permanent home for a longer period time and would have a positive effect on the individual's mental wellbeing. Introducing implicit techniques into everyday life could have a financial benefit to healthcare systems. If individuals are able to safely live in their home for a longer period of time, less pressure would-be put-on health care systems whilst also providing them with new ways to help older adults learn and adapted to new life challenges. As demonstrated in Chapter 7, both musicians and non-musicians with dementia show procedural learning for repeated sequences, with musicians showing faster motor skills than non-musicians. van Halteren-van Tilborg, Scherder and Hultsjin (2007) reviewed ways in which in-tact procedural learning can be used in rehabilitation in older adults with dementia. It is emphasised in the review that the practice of events are key to learning or relearning information. However, the amount of practice can be detrimental as too much can cause task fatigue and therefore reduce learning (van Halteren-van Tilborg et al., 2007). Constant practice (concentrating on one task at a time) of a skill is key to learning in dementia patients, as random practice includes divided attention and this is detrimental to learning (van Halteren-van Tilborg et al., 2007). This outlook can be applied to everyday living, For example, learning to use a microwave could be detrimental to everyday living. Many individuals with dementia have to move accommodation, by using repetitive procedural movements, for example walking between individual rooms to gain a map of the new surroundings or learning how to use appliances such as a shower, can make transitioning to a new home easier. It is important to develop training programs that use procedural or implicit learning techniques to help a safer living in those with dementia.

The current research looks at the difference between musicians and non-musicians on implicit memory tasks. All musicians were self-described professional musicians as well as active performers and had been involved in musical training from an early age. Learning music from an early age has been associated with improved cognitive and social-development outcomes (Southgate & Roscigno, 2009). However, little is known about how those benefits translate into later adult life. Previous research has looked at the lifetime benefits of musical training and discussed whether there is a sensitive period for learning a musical instrument that benefits motor performance in adult life (Watanabe, Savion-Lemieux & Penhune, 2007). Watanabe and colleagues (2007) compared the differences between early trained musicians (before 7 years of age) and late trained musicians (after 7 years of age) on timed motor sequence tasks. Results showed that early trained musicians performed better than late trained musicians on a motor sequence task. Third variable factors, for example partaking in other social activities, social status and performance/ practicing time, were not available for comparison. Therefore, it is unclear whether other factors were involved in the improved task performance in early trained musicians. It is important to understand whether there is a specific period in childhood that is best for learning an instrument that leads to memory benefits in later life, and whether an individual needs to be involved in musical training for a certain length of time for these benefits to continue into later life or whether training as a child forms structural brain changes that stay throughout a lifetime. Chapter 6 looks at the difference between active and less active non-musicians compared to professional musicians to see whether partaking in an active lifestyle shows the same cognitive benefits that is shown in those with musical training. This was not the case and although active non-musicians performed faster than less active non-musicians, musicians outperformed both groups of motor tasks. However, this was only looked at in older adults. If children partake in skilled activities that require the same intensity of training as musicians would this provide a cognitive benefit that like musical training spans over a lifetime.

8.2 Future research directions

To fully understand how much musical training can benefit health and wellbeing over a lifetime, longitudinal research is needed to look at the comparison between musicians and non-musicians over the life span. It is important to understand whether the performance on procedural tasks in musicians is due to musical training. To do this, other factors need to be taken into consideration. Children that take part in other multiple skill-based activities should be compared to both musicians and non-musicians over a period of time. As learning a musical instrument requires multiple hours or practice and performance time, other skilled activities used should be comparable in the length of practice. Having comparable activities will help understand whether taking part in musical training over the life span can answer for the benefits shown in musicians on motor tasks, or whether other intense social activities provide individuals with the same outcome.

Further research is needed to understand whether learning an instrument in later life can provide older adults without lifelong musical training with better performance on procedural tasks. If learning an instrument later in life does provide implicit and motor benefits to older adults without any prior musical experience, then it is important that more musical programs are developed and promoted to older adults to help support the completion of every day procedural tasks. Being able to perform everyday task will have a positive impact on the health and wellbeing of older adults as well as being able to live independently for a longer period of time.

Unlike explicit memory, some aspects of implicit learning did not decline in those with dementia, as performance on procedural learning tasks was comparable with that of healthy older adults. More research is needed to look at the way implicit memory can be used to benefit those with dementia. Most adults that are diagnosed with dementia require extra care and a move of accommodation. With the lack of explicit memory processes, these changes often come with mental health issues and confusion. It is important to look at how implicit memory techniques including association and repeated activity can be used to help with the learning of a new environment in a more relaxed manner.

8.3 Conclusion

The aim of the current research was to look at the possible benefit of musical training on implicit memory in both healthy older adults and individuals with dementia. It is already well established that musical training across the life span enhances cognitive process, specifically in the visuospatial and verbal domains and executive process in older adults (Hanna-Pladdy & Gajewski, 2012). These advantages in working memory have shown to be constant even when musicians are no longer active musicians in later life (Hanna-Pladdy & Gajewski, 2012). There is a lack of understanding whether musical training can benefit implicit memory. Implicit memory is often researched as one memory system despite the different process involved. The current research suggests that implicit memory and procedural learning are not the same, with differences shown between musicians and non-musicians on procedural learning tasks but little difference found in priming tasks. Overall, musicians performed faster than non-musicians on procedural learning tasks which implied better retention of capacity for procedural learning in those with long term musical training. Despite musicians performing better overall on both procedural and priming tasks, non-musicians also showed the use of implicit memory. Understanding how musical training can benefit implicit memory in older adults and individuals with dementia can be valuable in providing an insight into the use of music for possible health and motor advantages in later life. Musical training has been shown to preserve cognitive speed in both older adult musicians and musicians with dementia. Both groups perform better than non-musicians on the Serial Reaction Time Task, with dementia participants largely performing as well as healthy older adult non-musicians suggesting musical training benefits motor performance, and this remains in musicians with dementia. Better motor skills shown in musicians could lead to better living for both healthy older adults and individuals with dementia. Being able to successfully perform everyday tasks, for example, making a meal and getting dressed, could have a direct link to an improved quality of life and wellbeing in both older adults and individuals with dementia.

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Appendix 1: Audio example of the difference between a cadence and a non-cadence chord sequence (CD)

Track 1 – Example of a cadence ending

Track 2 – Example of a non-cadence ending

Appendix 2: Audio examples of the sequences used in the Adapted Phoneme Monitoring Task (CD)

Examples of the cadence and non-cadence sequences heard in the Adapted Phoneme Monitoring Task (Chapter 4,5,6 and 7).

Track 1-6 Example of sequences with cadence ending

Track 7-12 Example of sequences with non-cadence ending

Track 13- 15 Example of sequences heard in explicit memory task

Appendix 3: Published paper - Implicit knowledge and memory for musical stimuli in musicians and non-musicians (Chapter 4)

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Implicit knowledge and memory for musical stimuli in musicians and non-musicians

Lisa Thorpe, Margaret Cousins and Ros Bramwell

Abstract
The phoneme monitoring task is a musical priming paradigm that demonstrates that both musicians and non-musicians have gained implicit understanding of prevalent harmonic structures. Little research has focused on implicit music learning in musicians and non-musicians. This current study aimed to investigate whether the phoneme monitoring task would identify any implicit memory differences between musicians and non-musicians. It focuses on both implicit knowledge of musical structure and implicit memory for specific musical sequences. Thirty-two musicians and non-musicians (19 female and 13 male) were asked to listen to a seven-chord sequence and decide as quickly as possible whether the final chord ended on the syllable /*di*/ or /*du*/. Overall, musicians were faster at the task, though non-musicians made more gains through the blocks of trials. Implicit memory for musical sequence was evident in both musicians and non-musicians. Both groups of participants reacted quicker to sequences that they had heard more than once but showed no explicit knowledge of the familiar sequences.

Keywords
Music, musician, implicit learning, implicit memory

Music training has been related to differences in cognitive abilities in musicians. Specifically, research has shown that music training and instrumental performance is associated with enhanced cognitive function in speech and language processing (Tierney, Krizman, Skoe, Johnston, & Kraus, 2013), motor abilities (Costa-Giomi, 2005), attention and memory (Hansen, Wallentin, & Vuust, 2012). Much of the research into the effects of musical training has centred on working memory, especially the function of the phonological loop and the visuo-spatial sketchpad (Hansen, Walletin, & Vuust, 2012). Working memory research has shown that music

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training has positive effects at all life stages. A longitudinal study showed that children who participated in 45 minutes of weekly music lessons over an 18-month period performed better in phonological loop and central executive sub-tests compared to children who had received an equal amount of natural science training (Roden, Grube, Bongar, & Kreutz, 2014). In long-term memory tasks, both verbal learning (Franklin et al., 2008) and recall tasks showed that musicians performed better than non-musicians (Talamini, Altoe, Carretti, & Grassi, 2017).

There is an increased interest in the effects of musical training on implicit and explicit memory. Explicit memory is the conscious retrieval of information that has been intentionally learned (Warker & Halpern, 2005). Implicit memory is the retention of previously learned information without conscious recollection of learning it. Implicit learning is said to occur when participants improve in speed or accuracy for the previously learned information (Bergstorm, Howard, & Howard, 2012). Previous research has shown that musicians perform better than non-musicians on visuo-spatial sequence learning tasks (Anaya, Pisoni, & Kronenberger, 2017). However, little research has focused on implicit music learning in musicians and non-musicians. There is currently a need to devise an implicit music task that is accessible to both musicians and non-musicians enabling an insight into the effects of musical training on the processing of musical stimuli. This current study aimed to investigate whether an implicit musical memory task would identify any differences between musicians and non-musicians.

Implicit memory tasks use a variety of priming techniques that act on automatic processes. Priming occurs when a visual or auditory item is presented to the participant in the initial study phase of the task, which then facilitates an unconscious reaction or response to the same stimulus when presented later in the task (Ward, Berry, & Shanks, 2013). Many studies, for example, use a word stem completion task to show the unconscious encoding and retrieval of words, where participants are more likely to fill in word stems with items that have been previously viewed or heard (Tulving, Schacter, & Stark, 1982). Words and music have some similar characteristics. For example, they both require the use of timbral and pitch changes (Halpern & Müllensiefen, 2008; Warker & Halpern, 2005). However, due to the use of harmony, unfamiliar intervals, and rhythmic groupings, music can be more complex than language which can therefore make it harder for participants to code the information in the initial study stage (Warker & Halpern, 2005).

Warker and Halpern (2005) devised a tune stem completion task that was similar in structure to commonly used word stem completion tasks. In the initial learning phase, participants were asked to listen to a set of composed melodies: some unfamiliar tunes and some that were based on known folk tunes. In the following section, selected tunes finished after a chosen note, and participants were asked to hum/sing the next note that would fit best musically. Tunes consisted of melodies heard in the previous section and novel tunes. Results showed that participants completed more tunes correctly when they had been previously heard. Warker and Halpern (2005) also devised a preference task, where they investigated different characteristics of music, such as timbre, which they postulated could help with encoding and retrieval. As in their first study, results showed that participants correctly completed more tunes that they had previously heard. However, changing the characteristic of the stimuli (timbre) did not affect implicit memory or explicit memory. Peretz, Gaudreau, and Bonnel (1998) presented both familiar and unfamiliar melodies to participants in different implicit and explicit memory tasks. In both the implicit and the explicit condition, there was stronger liking and recognition of the familiar melodies (Peretz et al., 1998). In contrast to the findings of Warker and Halpern (2005), timbre changes were detrimental to explicit but not implicit recall (Halpern & Müllensiefen, 2008). The result found in all these studies shows that specific spectral characteristics of the music may be relevant to explicit learning but irrelevant for listeners' implicit memory.

While implicit memory for music can be demonstrated by using tasks that are similar to word stem completion tasks (Warker & Halpern, 2005), challenges may occur when using a musical production task as participants may feel exposed in humming or singing a response. In Warker and Halpern's study, some note productions were hard to score and data were incomplete. For this reason, tasks that do not require a vocalized response in order to demonstrate implicit learning of musical phrases may be more suitable, especially for non-musicians. The phoneme monitoring task (Bigand, Tillmann, Poulin, D'Adamo, & Madurall, 2001; Tillmann, Justus, & Bigand, 2008) is a musical priming paradigm used to investigate participants' implicit knowledge of tonal relations and harmonic structures. The study was focused on the prediction of harmonic relations and therefore aimed to look at harmonic priming rather than long-term memory. Bigand et al. (2001) presented an eight-chord strain that was sung using sampled synthesized vocal sounds, each chord sung to a different phoneme. Each sequence ended on either the phoneme */di/* or */du/*. Participants were asked to identify as quickly as possible to which phoneme the final chord was sung. Chord sequences were split into a conventional Western cadence, which Bigand et al. called the related condition (ending on the tonic chord) and an unconventional harmonic ending, which they called the less related condition (ending on the sub-dominant chord). The target chord for each condition was never heard in the previous context. Bigand et al. (2001) found that participants were quicker to react to the harmonically related chords than the less related chords. This suggests that participants are faster to react when a familiar harmonic structure facilitates phoneme retrieval (Tillmann et al., 2008). In other words, there is less attention paid to the conventional harmonic sequence, showing implicit understanding of Western harmonic structures. Participants were either music graduates or students with no formal music training and the effect was found even in the absence of formal musical literacy. Using the same paradigm, implicit musical structure knowledge has also been demonstrated in cerebellar patients who have impaired sequence learning (Tillmann et al., 2008). It should be noted, however, that in both of these studies, the penultimate chord for each type of sequence was different (the dominant for the related condition and the tonic for the unrelated), which may have cued participants to predict the final chord and which may have further facilitated the phoneme recognition.

In this present study, we adapted Bigand et al.'s (2001) phoneme monitoring task both to focus on implicit knowledge of musical structure and to study implicit memory for specific musical sequences. Both musicians and non-musicians took part to help us gain an understanding of whether musical training has impacted implicit memory and knowledge for musical structure and sequences. We have modified the task so that each sequence contains only seven chords to help the listener identify the end of the sequence which in common time represents a more commonly found rhythmic pattern ending on a strong beat. The first six phonemes were kept constant throughout all sequences and the final phoneme interchanged between the phoneme */du/* or */di/*. As in Bigand et al.'s study, the harmonically related condition ended with a perfect cadence on the tonic chord. However, we adapted the less related condition so that the preceding chord was the same penultimate chord (the dominant) in both conditions. This ensured that there was no pre-cueing of the final chord. In order for participants to differentiate between the cadence and non-cadence sequences, a key must first be inferred (Bigand et al., 2001). The root position of the final/target chord was not heard previously in the sequence; however, the chord was presented as an inversion to help establish the key of the sequence. Additionally, we have added an explicit knowledge test to determine whether participants gained any explicit awareness of any sequences that they had previously

Table 1. Demographic information for musicians and non-musicians.

Characteristics	Musician	Non-musician
Participants (*n*)	16	16
Male (*n*)	7	6
Female (*n*)	9	10
Age (years)		
M	27	24.25
SD	2	3.991
Years of musical training		
M	19.06	
SD	1.289	

heard. It was hypothesized that musicians would react quicker than non-musicians and that participants would react quicker to the phonemes attached to a conventional perfect cadence strain than the non-cadence sequences.

Method

Participants

Thirty-two young adults (19 female and 13 male) participated in the experiment: 16 musicians (seven male and nine female) and 16 non-musicians (six male and 10 female; Table 1). The criteria for each group were based on previous research (Hansen et al., 2012); musicians were defined as people who were of grade 5 performance standard or above and had previously attended formal training and actively participated in music performance. Non-musicians were defined as people who did not have any musical training and were currently not involved in any music organizations. Musicians consisted of classically trained music graduates from the University of Huddersfield, the Royal Welsh College of Music and psychology undergraduate students from the University of Chester with formal musical training. Non-musicians were university graduates and students from the University of Chester. No participating non-musicians had previous individual musical training. Two participants attended a musical theatre group but were considered as non-musicians due to no formal musical training and therefore their results were not removed from the analysis. All participants were English natives and had attended English schools and had only participated in music lessons according to the English national curriculum. The national curriculum is a set of standards and subjects followed by schools around the UK to ensure all students have the same learning experience are learning the same things (national curriculum, 2014). Music lessons involve basic listening skills and group activities; for example, classroom singing and music-making. However, this may not include formally learning an instrument or musical notation. All participants were tested individually at the University of Chester or at an organized rehearsal room and gave written consent for task participation.

Design and stimuli

The experiment used a mixed design, with repeated measures on harmonic relatedness, familiarity, and time of presentation, and with musician or non-musician as the grouping variable.

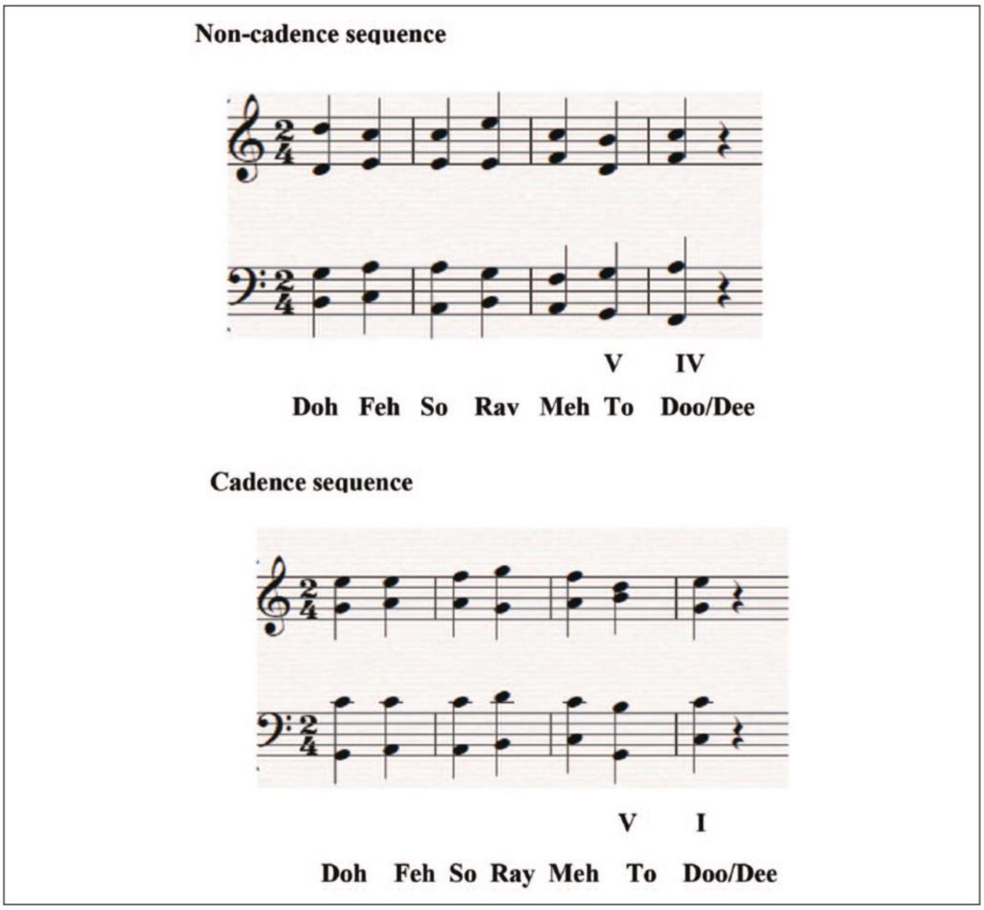

Figure 1. Example of cadence and non-cadence chord sequences used in the experiment.

Twenty-four different seven-chord sequences were developed using Sibelius 6 and recorded using the sample voice sounds on the Vocal Writer singing software, version 2.0 (Cecys, 1998). Care was taken to ensure all 24 sequences were distinct and not; for example, transpositions of the same sequence. Twelve were used in an initial phoneme detection task. The other 12 were subsequently used as novel stimuli to use as controls to compare with the first 12. Each chord was sung to a homogeneous phoneme. The first six syllables of every sequence were identical (*doh, fey, so, ray, meh, to*) and were selected according to the most easily distinguishable phonemes available on Vocal Writer. The final target chord was either the phoneme /*di*/ or /*du*/ (see Figure 1). These were retained from Bigand et al. (2001) as they had found that out of the 24 consonant-vowel phonemes used in their study, they were the easiest to distinguish. The sequences were then transferred to MP3 files and the experiment was conducted using e-Prime 2.0 software. The tempo of the sequences was 92 crochet beats per minute, meaning that the length of each sequence up to the onset of the target phoneme was 4005 ms. There was a programming delay of 92 ms before the start of each sequence. The response was then timed from that onset of the seventh chord in the sequence. Participants used the computer keyboard keys "A" for /*du*/ and "L" for /*di*/ to respond to all sequences. The experiment only moved on to the next sequence once the participant had pressed a response key. A three second inter-stimulus-interval of white noise separated each sequence. To control for any intrinsic difficulty effects the sequences were counterbalanced across participants so that, for example, the first participant would hear Figure 1 below with the /*du*/ ending and the second with the /*di*/ ending

Procedure

Participants were asked to listen to the sequence and decide as quickly as possible whether the final chord ended on the syllable /*di*/ or /*du*/. Before the experiment began, participants had three practice sequences that gave them feedback on whether they had answered correctly. The experiment was split into three blocks. The first block recorded reaction times and errors to the phoneme detection task. It consisted of 12 sequences: six cadence ending chords (three ending on the syllable *di* and three ending on *du*) and six non-cadence chords (three ending on /*du*/ and three ending on /*di*/). Three seconds of white noise was sounded after each sequence and the start of each new sequence was indicated with a beep. RT and errors to these novel stimuli were recorded. The second block consisted of 12 sequences, six sequences previously heard in block 1 (three cadence endings and three non-cadence endings), and six novel sequences (three cadence ending and three non-cadence ending). Participants were not informed that they had heard some of these sequences previously. Again, RT and errors were measured. The final block tested for explicit memory and consisted of 18 sequences (the six that had been presented in blocks 1 and 2, the six that had been novel in block 2, and the remaining six novel sequences). All were missing the final target chord. In this block participants were asked to 'guess' whether the sequence would finish either the syllable /*di*/ or /*du*/ and give a confidence rating, 1 = *not confident* to 4 = *confident*, of their answer. Here we assumed that if participants had explicit memory for the previously presented stimuli, they would be likely to perform at a level above chance on the previously heard sequences, but at chance on those they had not previously encountered. Within each block, all the sequences were presented in a random order that was generated by e-Prime.

Results

A mixed measures analysis of variance was conducted comparing repeated variables (time of presentation: block one, block two; Familiarity: repeated sequences, novel sequences; Sequence ending: cadence, non-cadence), with group (musicians and non-musicians) as the between-subject variable. An average reaction time was recorded for each variable and an overall average was taken for each group (see Table 2). Error rate was $<1\%$ and incorrect answers were not included in the averages. Reaction times were recorded from the start of the final chord (see Table 2 for reaction time results).

The ANOVA showed a significant main effect of time of presentation, $F(1, 30) = 31.817$, $p < .001$, $\eta p^2 = .515$. Participants reacted quicker to phonemes heard in the second block of trials compared to those heard in the first block. There was a significant main effect of relatedness (cadence and non-cadence), $F(1, 30) = 5.197$, $p = .030$, $\eta p^2 = .148$. Overall, participants responded quicker to phonemes for the chords ending on a cadence than those with the unconventional ending. A marginal effect of group, $F(1, 30) = 4.014$, $p = .054$, $\eta p^2 = .118$, showed that musicians reacted quicker than non-musicians overall.

Table 2. Mean reaction times (ms) for familiarity (repeated sequences, novel sequences); sequence ending (cadence, non-cadence) and time (block 1, block 2). Error rate was <1% and incorrect answers were not included in the averages.

Familiarity

		Repeated			Novel		
		Cadence	Non-cadence	Sub-total	Cadence	Non-cadence	Sub-total
Block 1	Musicians	981.563 (373.934)	963.818 (384.520)	972.691 (379.227)	971.288 (349.986)	953.543 (360.572)	962.416 (355.279)
	Non-musicians	1296.422 (371.424)	1348.193 (403.563)	1322.308 (387.494)	1261.761 (334.709)	1313.532 (366.849)	1287.647 (350.779)
	Subtotal	1138.993 (372.679)	1156.006 (394.042)	1147.500 (383.361)	1116.525 (342.348)	1133.538 (363.711)	1125.032 (353.029)
Block 2	Musicians	853.776 (392.879)	869.032 (440.713)	861.404 (416.796)	875.109 (372.989)	890.365 (420.823)	882.737 (396.906)
	Non-musicians	1005.583 (327.104)	1034.011 (324.493)	1019.797 (325.799)	1034.073 (339.760)	1062.801 (337.149)	1048.437 (338.455)
	Subtotal	929.680 (359.992)	951.522 (382.603)	940.601 (371.298)	954.591 (356.376)	976.583 (378.986)	965.587 (367.681)
Total		1034.307 (366.336)	1053.764 (388.323)		1035.558 (349.362)	1055.061 (371.349)	

There was a significant interaction of time of presentation and group, $F(1, 30) = 7.229$, $p = .012$, $\eta p^2 = .194$. Paired samples t-tests with an adjusted alpha level of $p < .025$ confirmed that both groups reacted quicker for chords in block 2 than block 1: musicians, $t(15) = 2.567$, $p = .021$, $d = .249$; non-musicians $t(15) = 5.090$, $p < .001$, $d = .783$. However, non-musicians showed greater improvement in reaction time for sequences heard in the second block compared to musicians. There was a significant interaction between time of presentation and familiarity, $F(1, 30) = 7.382$, $p = .011$, $\eta p^2 = .197$. Post hoc t-tests with an adjusted alpha level of $p < .025$ showed that for unfamiliar chords, participants were faster on the second block, $t(31) = 3.546$, $p = .001$, $d = .367$ (mean difference = 136 ms), suggesting an effect of practice on the task. Participants were also significantly faster on familiar chords in the second block, $t(31) = 5.606$, $p < .001$, $d = .566$, and here the larger mean difference between blocks for familiar sequences (230 ms) is suggestive of an additional effect of familiarity over and above practice effects.

Overall, participants reacted quicker to the repeated chord sequences that had been heard in both sections compared to the novel chord sequences that were only heard once. Results showed a significant interaction of relatedness and group, $F(1, 30) = 6.031$, $p = .020$, $\eta p^2 = .167$. Post hoc t-tests with adjusted alpha level of $p < .025$ showed a significant effect of sequence ending for non-musicians, $t(15) = -3.748$, $p = .002$, $d = 0.242$, who reacted quicker overall to the cadence ending than the non-cadence ending. There was no effect of relatedness for musicians, $t(15) = .094$, $p = .927$. No other effects were significant.

Explicit memory

In the final block, participants were asked to "guess" what the final syllable would be (Table 3). This was a forced choice answer – participants selected either /*di*/ or /*du*/ meaning that on

Table 3. Accuracy percentages for correct guesses in the explicit memory task.

	Accuracy		
	Musicians	Non-musicians	Subtotal
Block 1 and 2	52.1%	53.3%	52.7%
Block 2 only	53.8%	53.6%	53.7%

sequences which they had heard before and for which there was a "correct" answer, they would be expected to perform higher than chance if they had explicit memory of the sequence. A one-sample *t*-test was used to look at whether participants showed any explicit memory for musical sequences by comparing their responses to chance (a 50% accuracy for the choice of /*di*/ or /*du*/). This was analyzed using data from the third block by looking at accuracy for chord sequences that were heard in both blocks as well as sequences that were heard in block 2 only. Familiarity on accuracy scores showed that participants were performing at chance whether they had heard the sequences twice before the final block ($M = .527$, $SD = .171$), $t(31) = .880$, $p = .386$, or just once before the final block ($M = .537$, $SD = .192$), $t(31) = 1.085$, $p = .286$.

A Pearson's correlation coefficient was also calculated and confirmed that there was no correlation between accuracy of response and confidence ratings, $r(30) = -.75$, $p = .684$.

Discussion

The present experiment was designed to measure both implicit musical knowledge and to create a musical learning task to look at the implicit musical learning patterns of musicians and non-musicians. The results demonstrated that both groups showed signs of both implicit knowledge and implicit memory.

Implicit learning is observed when participants show an improvement in response to the stimuli that have been previously presented, without any explicit training on those stimuli. In this study, we used six sequences that were constant across all blocks. Results showed that both musicians and non-musicians reacted quicker to sequences that had been heard before than when the sequences that were unfamiliar. Unlike Bigand et al.'s (2001) study, we found some differences in performance between musicians and non-musicians. Both groups showed an improvement in reaction times between the first block of trials and the second block of trials, which contained some repeated material. While musicians were marginally faster at the task overall, non-musicians showed a greater improvement in reaction time between blocks. As it is unlikely that non-musicians had greater implicit learning of musical stimuli, their gains may well be attributed to practice effects. It can be concluded that participants were not guessing the phoneme ending, as we would expect the error rate to be on average of 50% if they were providing guess answers. As the error rate was less than 1% we can be confident that the processing time are that of real responses.

As in Bigand et al.'s (2001) study, participants were not asked to pay any explicit attention to the musical structure of the chord sequences, only the syllable of the final chord. This allowed the experiment to be used to test for harmonic priming by using modern Western cadence progressions in comparison to non-cadence chord structures. Results showed that participants reacted quicker to the cadence chord sequences compared to the non-cadence sequences. However, this varied by group; while results for non-musicians were in accordance with previous studies (Bigand et al., 2001; Tillmann et al., 2008) musicians were not affected by the structure of the cadence. A cognitive approach to harmonic priming shows that the Western harmony hierarchy of chords suggests that Western listeners internalize chords that are built on the tonic, subdominant, and dominant due to mere exposure to Western music and would therefore react faster to the cadence ending than the non-cadence (Bigand, Poulin, Tillmann, Madurell, & D'Adamo, 2003). An alternative explanation suggests that sensory priming, a chord that shares component chords or overtones with the final chord will be anticipated and therefore should have a faster reaction time. For example, a cadence ending shares more component tones than a non-cadence ending and therefore participants will anticipate the cadence ending more than the non-cadence (Bigand et al., 2003). However, we are unsure why musicians were unaffected by the cadence structure, but the differences between musicians and non-musicians might be explained through the amount of musical training musicians acquire.

As well as supporting previous research which shows implicit knowledge of musical structures, we were able to demonstrate a degree of implicit memory for previously heard musical sequences. While this was confounded with more general practice effects (participants were faster "across the board" in the second block of trials), the block by familiarity interaction indicates that gains made on previously heard sequences were greater than those for the novel sequences presented in the second block, with musicians performing faster overall. Our results support the findings of Conway, Pisoni, and Kronenberger (2009), which suggests that sound provides a framework, which they term the "auditory scaffolding process," which participants use to learn and process sequential auditory information. Differences in musical experience may enhance these sequencing skills. Francois and Schön (2011) supported the "auditory scaffolding process" where they found that increased exposure to sounds benefits implicit learning.

By adapting the phoneme task, we were able to look at the whether participants gained explicit knowledge from the sequences and therefore whether explicit memory affected reaction times. Explicit memory for musical sequences would be shown if participants performed above chance on those sequences that had been presented in section 2 and a further increase in accuracy for those that had been heard in both block 1 and 2. Six novel sequences that had not been heard before were used in the final section so a comparison could be made with confidence scores. As participants were not instructed to remember any information as part of the task, participants were asked to guess the ending of the sequence (whether the final syllable was /*du*/ or /*di*/) followed by giving the confidence level of their answer. As participants performed at chance (accuracy levels of approximately 50%) and there was no correlation between accuracy of answers and confidence levels, we were able to conclude that participants showed no signs of explicit knowledge of musical sequences.

To conclude, we have successfully adapted Bigand et al.'s (2001) priming task to test both implicit musical knowledge and more temporally contiguous implicit memory for sequences. By generating a test of implicit musical memory that is analogous to measure of implicit verbal and visuo-spatial memory is the first step to discovering the extent in which musicians might be advantaged in procedural and implicit memory tasks, and whether musicianship has the ability to preserve cognitive faculties in the procedural memory domain. Repetition within musical structures is common in much popular and classical music, and our study shows that such repetition may facilitate people's listening, even when they are not explicitly aware they have encountered a specific musical phrase a few minutes earlier. This effect is found for both musicians and non-musicians; while musicians process musical stimuli faster than non-musicians, the latter seem to gain more from repetition, though future research should attempt to disengage implicit memory from more general practice effects on the task.

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Appendix 4: Ethical approval for study 1 (Chapter 4)

University of Chester

UNIVERSITY OF CHESTER, DEPARTMENT OF PSYCHOLOGY
APPLICATION FOR ETHICAL APPROVAL AMENDMENT FORM

A) **Applicant and personnel**

Applicant: *Lisa Thorpe*
Project title: Speed of processing of musical stimuli
Applicant status: ☐ Staff → Go to Section B ☒PGR ☐Undergraduate ☐Postgraduate taught
Supervisor: *Margaret Cousins*

B) **Declaration**

1. ☒ I have submitted an application for ethical approval to the Department of Psychology Ethics Committee and I am required to make the following amendments to my application.
List the recommendations of the committee.
Full researchers' and SSG contact details needed on all documentation
Eligibility criteria (need full hearing) to go on all materials
Ros Bromwell's role to be stated on supporting details
Participants to be able to set volume
Permission required from local music groups
Submit sample of audio stimuli
How long will the data be stored for?
RPS credits to be included on the information sheet

Describe how you have addressed these requirements.
Student support and supervisor details has been added to the information sheet and debrief (see appendix i and ii)
Eligibility criteria has been included on the information sheet, vocal protocol and the RPS information (see appendix i and iii)
Ros Bromwell's details have been included, under supervisor, on the information sheet and debrief (see appendix i and ii)
It has been included on the information sheet that participants can set the volume of the sung chords (see appendix i)
After ethics has been approved, I will contact local music groups to gain permission to approach members of the group (see appendix iv for recruitment email)
See appendix v for a sample of the music sequences
I have added that data will be stored for up to 5 years on the information sheet under the heading 'How will my information be used?' (see appendix i)
Information about RPS credits has been added to the information sheet (see appendix i)

2. ☐ I have submitted an application for ethical approval to the Department of Psychology Ethics Committee that was approved on Click here to enter a date.
I wish the committee to consider the following amendments I would like to make to the research plan (attach the original approved application form) *Click here to enter text.*

☐ I am a member of staff. **Signed:** ______________________ **Date:** Click here to enter a date.
Print the amendment form on BLUE PAPER and submit to the Dept. Office
☒ I am an UG/PGT/PGR student. I have discussed any amendments with my project supervisor.
Print the amendment form on BLUE PAPER and submit to the Dept. Office

Signed: L. Thorpe. **(Lead Applicant) Date:** 25/01/2017

Supervisor comments:
I have discussed the recommendations of the committee with the applicant and I am satisfied they have met the stated requirements./I support the amendments to the research plan. (delete as appropriate)
☑ Yes Sign and date the form ☐ No Comments: *Click here to enter text.*

Dopec LTMC270117

COMMITTEE COMMENTS:

☑ **ACCEPTABLE: You may now commence with data collection subject to approval from any relevant external agencies.**

DATA COLLECTION IS NOT PERMISSABLE UNDER THESE CONDITIONS

☐ **ACCEPTABLE SUBJECT TO SUBMISSION OF FURTHER AMENDMENT FORM.**

- ☐ **Acceptable subject to conditions listed by chair. Discuss conditions highlighted with supervisor and submit ethics application amendment form direct to office.**
- ☐ **Acceptable subject to conditions listed by chair: Submit ethics application amendment form direct to office.**

Signed: Moira E. Lafferty **Date:** Click here to enter a date. 27/01/17

Appendix 5: Information Sheet for participants (Chapter 4)

Participant Information Sheet

Participant number

Project title: Speed of processing of musical stimuli

Investigator: *Lisa Thorpe*

Invitation to participate

You are being invited to take part in a research study. Taking part is voluntary therefore it is up to you to decide whether or not to take part. It is important for you to understand what the research is about and what it will involve. Please do not take part if you have been diagnosed with any neurological or hearing deficiencies. Please take time to read the following information carefully; there will also be an opportunity to discuss all information if you have any uncertainties.

What is the project about?

The aim of this study is to look at differences between musicians and non-musicians on a phoneme recognition task. This study forms part of my PhD thesis.

What will I be asked to do?

You will be asked to take part in a computerized perception test. This requires:

- Listen to a sequence of eight sung chords and decide as quickly and as accurately as possible whether the final chord is sung to the sound dee or doo.

- To react to the final chord, you will be asked to press an allocated key on the keyboard.

- There are three separate sections each consisting of 24 sequences. Instructions for each section will be shown on screen.

- Participants will be able to set the volume of the sung chords.

Altogether these perception tasks will take approximately 30 minutes. The University of Chester psychology students will earn 2 RPS credits for taking part in this study.

What are the advantages and disadvantages of taking part?

By taking part you will be adding to our understanding of how we process musical stimuli.

Taking part in this study should not cause any discomfort or distress. However, if feelings do arise as a consequence of taking part, you can seek advice or support via your Personal academic tutor, visit student welfare located in Binks 113 or contact student support- Student.support@chester.ac.uk 01244 511550

How will my information be used?

The information collected during this study will be used to produce a research article that will be used as part of my PhD thesis. The information may be published in academic journals, presented at academic conferences, or used for teaching purposes and therefore will be stored securely for up to five years. Although the information may be used for these purposes, you will not be identifiable in any way through these activities. Participant numbers will be allocated to keep anonymity and all details confidential. Your participant number can be found at the top of this information sheet.

Will my information be confidential?

All the information you provide will be treated in confidence. This means that your name will not be passed on to anyone else and your information will be used solely for the research or teaching purposes of the university. All your information will be stored securely and only my project supervisors and I will have access to each person's individual information.

Can I change my mind?

Yes, you can stop taking part in the study at any time. You can also ask for part or all your data to be destroyed before leaving the testing venue. Once you have left the room data will not be able to be removed.

Who can I contact for further information?

Lisa Thorpe – l.thorpe@chester.ac.uk

Supervisors

Dr Margaret Cousins- m.cousins@chester.ac.uk 01244 511686

Professor Ros Bramwell- r.bramwell@chester.ac.uk 01244 511477

What happens next?

Please think carefully about whether or not you wish to take part in the study. If you do wish to take part, please complete the attached consent form.

Thank you for considering participating.

Appendix 6: Consent Form completed by participants (Chapter 4)

Consent Form

Project Title: Speed of processing of musical stimuli

Investigator: *Lisa Thorpe*

Please indicate your agreement by ticking the following boxes after each of the statements and sign where indicated below:

1. I confirm that I have read and understood the information sheet for the above study
and understand what is expected of me. ☐
2. I understand that my participation is completely voluntary. ☐
3. I understand that I am free to stop the study at any time and I am free to withdraw my
data before leaving the testing venue. If the data is collected anonymously and it will be impossible to identify the participant's data after they have left the session then they must be informed accordingly (i.e., once they leave the session they will no longer be able to withdraw their data) ☐
4. I confirm that I have been given the opportunity to ask questions regarding the study,
and if asked, the questions were answered to my full satisfaction. ☐

Data Protection Act

I understand that data collected from me during this study will be stored on computer and that any computer files containing information about me will be made anonymous. I also understand that this consent form will be stored separately in a secure location from any data that I provide.

I agree to the University of Chester recording and processing my data and that these data will be used for a PhD thesis, and may be presented in other academic forums (e.g., academic journals, at conferences, or in teaching). I understand that my data will be used only for these purposes and my consent is conditional upon the University complying with its duties and obligations under the Data Protection Act.

Your name (print) …………………………………

Your signature ………………………………… Date ………………..

Researcher's name (print) …………………………………

Researcher's signature ………………………………… Date ………………..

Thank you for this information. Please do not hesitate to contact us if you have any questions.

Appendix 7: Debrief for study 1 (Chapter 4)

Debrief

Project Title: Speed of processing of musical stimuli

Thank you for taking part in my study.

Previous research has established that both musicians and non-musicians performed equally on implicit musical knowledge tasks, such as the phoneme monitoring task you undertook. Implicit knowledge tasks require participants to use information that they acquired throughout life, without participants realising. The current study uses an adapted version of the phoneme monitoring task that looks at implicit learning. Some of the sequences that were heard in section 1 were then repeated in section 2. We expect that musicians will react quicker to those sequences that they have heard previously due to musical training. The aim of this study is to test whether musical training has enhanced implicit learning for tonal-harmonic music.

Please remember that because all data is anonymous you will not be able to withdraw from the study once you have left the testing venue.

If you have felt any discomfort or distress as a consequence of this study, please do not hesitate to seek advice via your personal assigned tutor, visit student welfare located in Binks 113 or contact student support - Student.support@chester.ac.uk 01244 511550

If you have any questions regarding the study, please contact;

Lisa Thorpe – l.thorpe@chester.ac.uk

Dr Margaret Cousins- m.cousins@chester.ac.uk 01244 511686

Professor Ros Bramwell- r.bramwell@chester.ac.uk 01244 511477

Once again, thank you for taking part in my research.

Lisa Thorpe

Appendix 8: Demographic Questionnaire (Chapter 4)

Questionnaire

Participant number: ______________

Age: ____________

Gender:

Male ☐ Female ☐ Do not identify as either ☐ Prefer not to say ☐

Musical experience:

Non-musicians ☐

Musicians ☐

Number of years of musical training:

Appendix 9: Ethical approval for study 2 (Chapter 5)

University of Chester

UNIVERSITY OF CHESTER, DEPARTMENT OF PSYCHOLOGY
APPLICATION FOR ETHICAL APPROVAL AMENDMENT FORM

A) Applicant and personnel

Applicant: *Lisa Thorpe*
Project title: Implicit memory of musical sequences
Applicant status: ☐ Staff → Go to Section B ☒PGR ☐Undergraduate ☐Postgraduate taught
Supervisor: *Margaret Cousins*

B) Declaration

1. ☒ I have submitted an application for ethical approval to the Department of Psychology Ethics Committee and I am required to make the following amendments to my application.
List the recommendations of the committee.
Reworded the statement relating to hearing loss on RPS information and verbal protocol.
Describe how you have addressed these requirements.
Sentence has been changed on both documents. See appendix i

2. ☐ I have submitted an application for ethical approval to the Department of Psychology Ethics Committee that was approved on Click here to enter a date.
I wish the committee to consider the following amendments I would like to make to the research plan (attach the original approved application form) Click here to enter text.

☐ I am a member of staff. **Signed:** ______________________ **Date:** Click here to enter a date.
Print the amendment form on BLUE PAPER and submit to the Dept. Office
☒ I am an UG/PGT/PGR student. I have discussed any amendments with my project supervisor.
Print the amendment form on BLUE PAPER and submit to the Dept. Office

Signed: ______________________ **(Lead Applicant) Date:** 23/11/2016

Supervisor comments:
I have discussed the recommendations of the committee with the applicant and I am satisfied they have met the stated requirements./I support the amendments to the research plan. (delete as appropriate)
☐ Yes Sign and date the form ☐ No Comments: Click here to enter text.

Signed: ______________________ **(Supervisor) Date:** 23/11/17

Dopec LTMC 281117

COMMITTEE COMMENTS:

☑ **ACCEPTABLE: You may now commence with data collection subject to approval from any relevant external agencies.**

DATA COLLECTION IS NOT PERMISSABLE UNDER THESE CONDITIONS

☐ ACCEPTABLE SUBJECT TO SUBMISSION OF FURTHER AMENDMENT FORM.

☐ **Acceptable subject to conditions listed by chair. Discuss conditions highlighted with supervisor and submit ethics application amendment form direct to office.**

☐ **Acceptable subject to conditions listed by chair: Submit ethics application amendment form direct to office.**

Signed: ____________ **Date:** Click here to enter a date. 27/11/17

Appendix 10: Information Sheet given to participants (Chapter 5)

Project title: Detecting sung syllables

Investigator: *Lisa Thorpe*

Invitation to participate

You are being invited to take part in a research study. Taking part is voluntary therefore it is up to you to decide whether or not to take part. It is important for you to understand what the research is about and what it will involve. Please do not take part if you have been diagnosed with any neurological or hearing deficiencies. Please take time to read the following information carefully; there will also be an opportunity to discuss all information if you have any uncertainties.

What is the project about?

The aim of this study is to look at differences between musicians and non-musicians on a phoneme recognition task. This study forms part of my PhD thesis.

What will I be asked to do?

You will be asked to take part in a computerized perception test. This requires:

- Listen to a sequence of seven sung chords and decide as quickly and as accurately as possible whether the final chord is sung to the sound dee or doo.
- To react to the final chord, you will be asked to press an allocated key on the keyboard.
- There are seven separate sections each consisting of 12-18 sequences. Instructions for each section will be shown on screen.
- Participants will be able to set the volume of the sung chords.

Altogether these perception tasks will take approximately 30 minutes. The University of Chester psychology students will earn 2 RPS credits for taking part in this study.

What are the advantages and disadvantages of taking part?

By taking part you will be adding to our understanding of how we process musical stimuli.

Taking part in this study should not cause any discomfort or distress. However, if feelings do arise as a consequence of taking part, you can seek advice or support via your Personal academic tutor, visit student welfare located in Binks 113 or contact student support- Student.support@chester.ac.uk 01244 511550

How will my information be used?

The information collected during this study will be used to produce a research article that will be used as part of my PhD thesis. The information may be published in academic journals, presented at academic conferences, or used for teaching purposes and therefore will be stored securely for up to five years. Although the information may be used for these purposes, you will not be identifiable in any way through these activities. Participant numbers will be allocated to keep anonymity and all details confidential. Your participant number can be found at the top of this information sheet.

Will my information be confidential?

All the information you provide will be treated in confidence. This means that your name will not be passed on to anyone else and your information will be used solely for the research or teaching purposes of the university. All your information will be stored securely and only my project supervisors and I will have access to each person's individual information.

Can I change my mind?

Yes, you can stop taking part in the study at any time. You can also ask for part or all your data to be destroyed before leaving the testing venue. Once you have left the room data will not be able to be removed.

Who can I contact for further information?

Lisa Thorpe – l.thorpe@chester.ac.uk

Supervisors

Dr Margaret Cousins- m.cousins@chester.ac.uk 01244 511686

Professor Ros Bramwell- r.bramwell@chester.ac.uk 01244 511477

What happens next?

Please think carefully about whether or not you wish to take part in the study. If you do wish to take part, please complete the attached consent form.

Thank you for considering participating.

Appendix 11: Consent form (Chapter 5)

Consent Form

Project Title: Detecting sung syllables

Investigator: *Lisa Thorpe*

Please indicate your agreement by ticking the following boxes after each of the statements and sign where indicated below:

1. I confirm that I have read and understood the information sheet for the above study and understand what is expected of me. ☐

2. I understand that my participation is completely voluntary. ☐

3. I understand that I am free to stop the study at any time and I am free to withdraw my data before leaving the testing venue. If the data is collected anonymously and it will be impossible to identify the participant's data after they have left the session then they must be informed accordingly (i.e., once they leave the session they will no longer be able to withdraw their data) ☐

4. I confirm that I have been given the opportunity to ask questions regarding the study, and if asked, the questions were answered to my full satisfaction. ☐

Data Protection Act

I understand that data collected from me during this study will be stored on computer and that any computer files containing information about me will be made anonymous. I also understand that this consent form will be stored separately in a secure location from any data that I provide.

I agree to the University of Chester recording and processing my data and that these data will be used for a PhD thesis, and may be presented in other academic forums (e.g., academic journals, at conferences, or in teaching). I understand that my data will be used only for these purposes and my consent is conditional upon the University complying with its duties and obligations under the Data Protection Act.

Your name (print) …………………………………

Your signature ………………………………… Date ………………..

Thank you for this information. Please do not hesitate to contact us if you have any questions.

Appendix 12: Debrief for study 2 (Chapter 5)

Debrief

Project Title: Implicit memory for musical sequences

Thank you for taking part in my study.

Previous research has established that both musicians and non-musicians performed equally on implicit musical knowledge tasks, such as the phoneme monitoring task you undertook. Implicit knowledge tasks require participants to use information that they acquired throughout life, without participants realising. The current study uses an adapted version of the phoneme monitoring task that looks at implicit memory for musical sequences. The sequences that were heard in section 1 were then repeated in section 2-5. All sequences in section 6 were novel sequences. We expect that both musicians and non-musicians will show improvements in reaction time throughout sections 1-5. Reaction times for section 6 will be slower for both groups however, it is expected that musicians will show less practice effect than and therefore will have quicker reaction times than non-musicians. Section 7 was a test of explicit knowledge gained throughout the task. Explicit knowledge is the conscious awareness of information. It is expected that participants will not show signs of explicit knowledge.

Please remember that because all data is anonymous you will not be able to withdraw from the study once you have left the testing venue.

If you have felt any discomfort or distress as a consequence of this study, please do not hesitate to seek advice via your personal assigned tutor, visit student welfare located in Binks 113 or contact student support - Student.support@chester.ac.uk 01244 511550

If you have any questions regarding the study, please contact;

Lisa Thorpe – l.thorpe@chester.ac.uk

Dr Margaret Cousins- m.cousins@chester.ac.uk 01244 511686

Professor Ros Bramwell- r.bramwell@chester.ac.uk 01244 511477

Once again, thank you for taking part in my research.

Lisa Thorpe

Appendix 13: Demographic questionnaire (Chapter 5)

Questionnaire

Participant number: _______________

Age: _____________

Gender:

Male ☐ Female ☐ Do not identify as either ☐ Prefer not to say ☐

Musical experience:

Non-musicians ☐

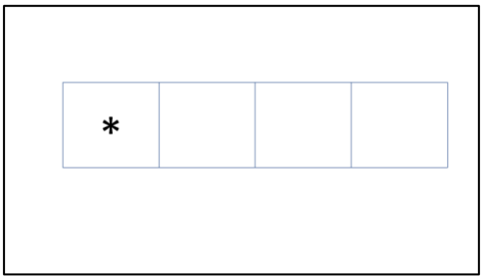
Musicians ☐

Number of years of musical training:

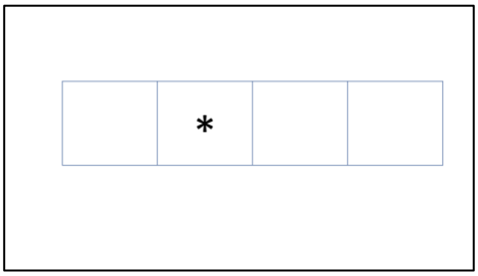
Appendix 14: Example of the Serial Reaction Time Task (Chapter 6 and 6)

Serial Reaction time task

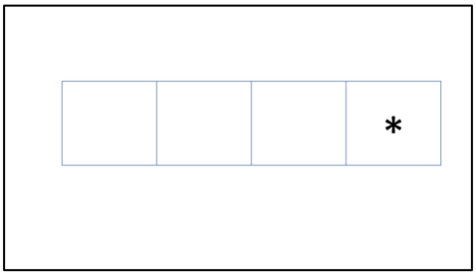
Screen 1



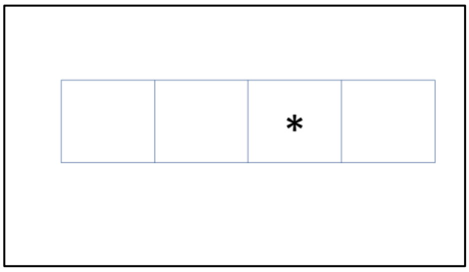
Screen 2



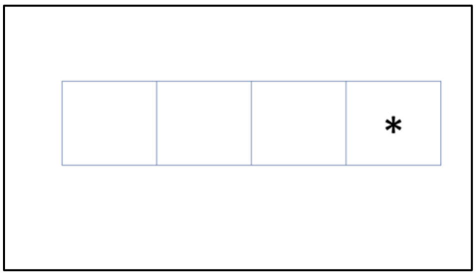
Screen 3



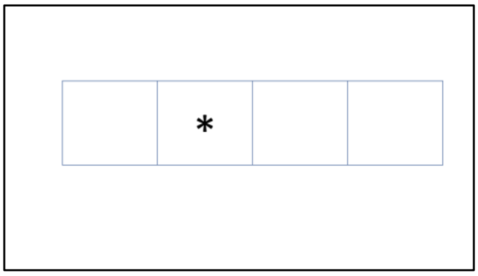
Screen 4



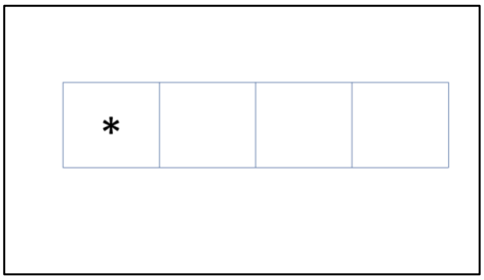
Screen 5



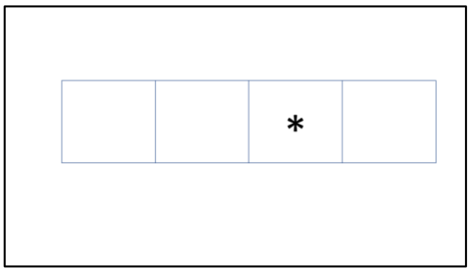
Screen 6



Screen 7



Screen 8



Appendix 15: Word Completion task (Chapter 6 and 7)

Words completion task based on Anderson (1999)

25 used in both studying and fragment section

1)	behind	b _ h _ _ _
2)	insure	i n _ _ r e
3)	exceed	e x _ e _ _
4)	mutter	m u _ _ e r
5)	pride	p r _ _ e
6)	speak	s p e a _
7)	flipper	f l i _ _ e r
8)	explore	e x p l _ _ e
9)	warm	w _ _ m
10)	kite	k i _ _
11)	tape	t _ p _
12)	hare	h _ r _
13)	after	a _ t _ r
14)	chore	c h o _ e
15)	sample	s _ m p _ _
16)	attach	a t t _ c _
17)	compact	c _ m p _ _ t
18)	dessert	d e s _ _ _ _
19)	shale	s h _ l _
20)	short	s h o _ t
21)	repeat	r _ p _ _ t
22)	strife	s t r _ _ e
23)	line	l _ _ e
24)	born	b _ r n
25)	stereo	s t _ r _ o

<u>25 words used in study phase only</u>

1) try

2) was

3) fame

4) slip

5) book

6) ripe

7) forest

8) offset

9) lemon

10) create

11) starry

12) match

13) furry

14) taste

15) nifty

16) window

17) winked

18) vision

19) engage

20) screen

21) hotrod

22) telephone

23) dismissed

24) central

25) Provide

25 fragments used in the fragment section only with answers based on Anderson (1999)

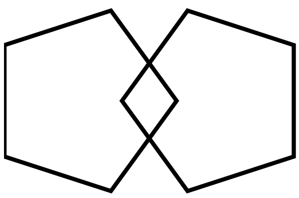
1) p _ _ s o n Person

2)	p _ s t _ r	Pester
3)	m _ _ g l e	Muggle
4)	b l _ n d	Blend
5)	s n _ r e	Snare
6)	b _ e	Bye
7)	h _ t	Hit
8)	g _ _ p e	Grape
9)	s m _ c k	Smock
10)	s m _ _ e	Smile
11)	k n _ _ _	Knock
12)	t _ n e	Tune
13)	s _ _ b	Slob
14)	s h _ r _	Shore
15)	d r _ _ n	Drain
16)	p _ _ n e	Phone
17)	a n g _ _	Angle
18)	f l _ _ t	Flirt
19)	f i _ _ t	First
20)	p _ c k	Pack
21)	h a _ e	Hate
22)	a _ t	Art
23)	c _ t	Cat
24)	w _ n	Win
25)	a _ e	Are

Appendix 16: Word Completion Task answer sheet (Chapter 6 and 7)

1. e x p l _ _ e
2. h _ r _
3. w _ n
4. g _ _ p e
5. s t _ r _ o
6. b _ r n
7. l _ _ e
8. p _ _ s o n
9. m _ _ g l e
10. f l _ _ t
11. r _ p _ _ t
12. a _ t _ r
13. s h o _ t
14. k n _ _ _
15. s m _ _ e
16. a _ t
17. s h _ l _
18. d e s _ _ _ _
19. i n _ _ r e
20. t _ n e
21. d r _ _ n
22. h a _ e
23. p _ _ n e
24. a t t _ c _
25. c h o _ e
26. c _ m p _ _ t
27. a _ e
28. f i _ _ t
29. h _ t
30. p r _ _ e
31. w _ _ m
32. k i _ _
33. s m _ c k
34. s n _ r e
35. b _ h _ _ _
36. e x _ e _
37. f l i _ _ e r
38. p _ c k
39. a n g _ _
40. s _ m p _ _
41. b _ e
42. b l _ n d
43. s p e a _
44. t _ p _
45. c _ t
46. s h _ r _
47. s t r _ _ e
48. s _ _ b
49. p _ s t _ r
50. m u _ _ e r

Appendix 17: Mini Mental State examination (Chapter 6 and 7)

One point for each answer **DATE:**			
ORIENTATION Year Season Month Date Time	……/ 5	……/ 5	……/ 5
Country Town District Hospital Ward/Floor	……/ 5	……/ 5	……/ 5
REGISTRATION Examiner names three objects (e.g. apple, table, penny) and asks the patient to repeat (1 point for each correct. THEN the patient learns the 3 names repeating until correct).	……/ 3	……/ 3	……/ 3
ATTENTION AND CALCULATION Subtract 7 from 100, then repeat from result. Continue five times: 100, 93, 86, 79, 65. (Alternative: spell “WORLD” backwards: DLROW).	……/ 5	……/ 5	……/ 5
RECALL Ask for the names of the three objects learned earlier.	……/ 3	……/ 3	……/ 3
LANGUAGE Name two objects (e.g. pen, watch).	……/ 2	……/ 2	……/ 2
Repeat “No ifs, ands, or buts”.	……/ 1	……/ 1	……/ 1
Give a three-stage command. Score 1 for each stage. (e.g. “Place index finger of right hand on your nose and then on your left ear”).	……/ 3	……/ 3	……/ 3
Ask the patient to read and obey a written command on a piece of paper. The written instruction is: “Close your eyes”.	……/ 1	……/ 1	……/ 1
Ask the patient to write a sentence. Score 1 if it is sensible and has a subject and a verb.	……/ 1	……/ 1	……/ 1
COPYING: Ask the patient to copy a pair of intersecting pentagons 	……/ 1	……/ 1	……/ 1
TOTAL:	……/ 30	……/ 30	……/ 30

MMSE scoring 24-30: no cognitive impairment 18-23: mild cognitive impairment 0-17: severe cognitive impairment

Appendix 18: Ethical approval for study 3 (Chapter 6)

University of Chester

UNIVERSITY OF CHESTER, DEPARTMENT OF PSYCHOLOGY
APPLICATION FOR ETHICAL APPROVAL AMENDMENT FORM

A) Applicant and personnel

Applicant: *Lisa Thorpe*
Project title: Benefits of musical training on Implicit memory in older adults.
Applicant status: ☐ Staff → Go to Section B ☒PGR ☐Undergraduate ☐Postgraduate taught
Supervisor: *Margaret Cousins*

B) Declaration

1. ☒ I have submitted an application for ethical approval to the Department of Psychology Ethics Committee and I am required to make the following amendments to my application.
List the recommendations of the committee. *1)Use the word 'You will be able to' rather than 'Participants will be able to'*
2)Clarify what 'the sound doo or dee' means
3)Change demographic questionnaire so that 'other' is included in the gender options.
4)Change the language in the recruitment email so that it is not so complex
5)Managing participant distress
6)Needs to include Notification that materials used in the study are not diagnostic tools/therapy, Incentives/Compensation, How partially collected data will be used
7) Some testing to take place off campus in rehearsal buildings etc. said that friends/family will be informed of location. Might also be worth thinking of supervisor being involved as well.
8) applicant needs to clarify place of study
9) not clear what analysis will occur

Describe how you have addressed these requirements. *1)See appendix I for change in wording*
2) Included explanation that each chord is sung on a different syllable and the final chord is sung on the syllable dee or doo see appendix i.
3)See appendix ii for change of gender options
4)I have changed the language of the recruitment email and vocal protocol so the tasks described in lay terms see appendix iii
5)I have added a procedure in the event that participants show signs of distress. This can be seen in Appendix iv where I have adapted question 9 of ethics application.
6) Please refer to information sheet (Appendix i)
7) Please refer to Ethics form risk assessment which states supervisor's involvement.
8) Please refer to Ethics Question 9. Data collection will be completed at the rehearsal rooms and club locations. These will happen before/after the club time as to not disturb the activity. Times will be arranged for each participant once ethics has been granted.
9) I have added the analysis and software I will use to my ethics for please see Appendix v (question 18)

2. ☐ I have submitted an application for ethical approval to the Department of Psychology Ethics Committee that was approved on Click here to enter a date.
I wish the committee to consider the following amendments I would like to make to the research plan (attach the original approved application form) Click here to enter text.

☐ I am a member of staff. **Signed:** ______________________ **Date:** Click here to enter a date.
Print the amendment form on BLUE PAPER and submit to the Dept. Office
☒ I am an UG/PGT/PGR student. I have discussed any amendments with my project supervisor.
Print the amendment form on BLUE PAPER and submit to the Dept. Office

Signed: LThorpe ______________________ **(Lead Applicant) Date:** 08/02/2018

Supervisor comments:

COMMITTEE COMMENTS:

☑ **ACCEPTABLE: You may now commence with data collection subject to approval from any relevant external agencies.**

DATA COLLECTION IS NOT PERMISSABLE UNDER THESE CONDITIONS

☐ ACCEPTABLE SUBJECT TO SUBMISSION OF FURTHER AMENDMENT FORM.

☐ **Acceptable subject to conditions listed by chair. Discuss conditions highlighted with supervisor and submit ethics application amendment form direct to office.**

☐ **Acceptable subject to conditions listed by chair: Submit ethics application amendment form direct to office.**

Signed: Moira Sheehan **Date:** Click here to enter a date. 3/2/15

Appendix 19: Participant information sheet for study 3 (Chapter 6)

Participant Information Sheet

Project title: Benefits of musical training in older adults

Investigator: *Lisa Thorpe, post-graduate student at the University of Chester*

Invitation to participate

Adults over the age of 65 years old are invited to take part in a study looking at the benefits of musical training on later life. Taking part is voluntary therefore it is up to you to decide whether or not to take part. It is important for you to understand what the research is about and what it will involve. Please do not take part if you have been diagnosed with any neurological conditions or hearing problems that are not corrected to a normal level of hearing by hearing aids. Please take time to read the following information carefully; there will also be an opportunity to discuss all information if you have any uncertainties.

What is the project about?

The aim of this study is to look at differences between musicians and non-musicians on three different kinds of tasks. You do not have to be musical to be able to do the tasks. This study forms part of my PhD thesis.

What will I be asked to do?

You will be asked some questions about your lifestyle and your experiences. Then I will ask you to take part in some tasks. If you do not wish to take part in any or all of these tasks that is fine – just let me know. You will be asked to:

<u>Music task:</u>

- Listen to a sequence of seven sung chords where each chord is sung on a different syllable. Decide as quickly and as accurately as possible whether the final chord is sung on the syllable dee or doo.

- To react to the final chord, you will be asked to press an allocated key on the computer keyboard.

- There are seven separate sections each consisting of 12-18 sequences. Instructions for each section will be shown on screen.

- You will be able to set the volume of the sung chords so it is comfortable for you.

<u>Reaction time task</u>

- You will see three white circles and one black circle. Each circle will correspond to the position of an allocated key on the keyboard.

- React as accurately and quickly as possible to the position of the black circle.

- There are 6 sections in total each consisting of 100 black circles.

<u>Reading task</u>

- You will be asked to read a list of words that appear on the screen. There will be 50 words in total.

- Each word will appear on the computer screen. You will be able to control the speed that each word appears on the screen.

Altogether these perception tasks will take approximately 1 hour. None of these tests will be used to diagnose any medical or psychological condition.

What are the advantages and disadvantages of taking part?

By taking part you will be adding to our understanding of the benefits of musical training, and in particular whether it has any benefits for older adults.

Taking part in this study should not cause any discomfort or distress. However, if negative feelings do arise as a consequence of taking part, you can seek advice or support from the numbers below

Age UK advice – 0800 169 6565- website- www.ageuk.org.uk

How will my information be used?

The information collected during this study will be used to produce a research article that will be used as part of my PhD thesis. The information may be published in academic journals, presented at academic conferences, or used for teaching purposes and therefore data will be stored securely for up to five years. Although the information may be used for these purposes, no-one reading the article will be able to identify that you took part or how you did in the tests because we will be looking primarily at how the different groups did. If we do look at individual data, everything will be anonymised so no-one reading can know whose it is.

Will my information be confidential?

All the information you provide will be treated in confidence. This means that your name will not be passed on to anyone else and your information will be used solely for the research or teaching purposes of the university. All your information will be stored securely and only my project supervisors and I will have access to each person's individual information.

Can I change my mind?

Yes, you can stop taking part in the study at any time and if there is any particular test you don't wish to do, or question you don't want to answer, that's fine. You can also ask for part or all your data to be destroyed before leaving the testing venue. Once you have left the room data will not be able to be removed because it will be anonymous and I will not know whose is whose.

Who can I contact for further information?

Lisa Thorpe – l.thorpe@chester.ac.uk

Supervisors

Dr Margaret Cousins- m.cousins@chester.ac.uk 01244 511686

Professor Ros Bramwell- r.bramwell@chester.ac.uk 01244 511477

What happens next?
Please think carefully about whether or not you wish to take part in the study. If you do wish to take part, please complete the attached consent form.

Thank you for considering participating.

Appendix 20: Participant debrief for study 3 (Chapter 6)

Project Title: Benefits of musical training in older adults

Thank you for taking part in my study.
Previous research has established that young adult musicians and non-musicians performed equally well on tasks that involve understanding how music 'works' even without formal musical training. When we listen to a lot of music we learn lots about it, like learning English grammar even if we don't know much about what verbs and nouns are. However, research also suggests that musicians are better at some other kinds of tasks, perhaps because their brains develop differently to other people's. Psychologists call the kind of knowledge we gain without even realising it 'implicit memory'.

There's currently no research that looks at the benefits of music training on implicit memory of older adults. The study you took part in used 3 implicit memory tasks: the phoneme monitoring task, Serial reaction time task and a word fragment completion task. In the phoneme monitoring task and the serial reaction time task there were sequences that you encountered that were repeated later on in the test. We expect that participants will show improvements in reaction time as their ears and eyes got used to the sequences, even if you didn't notice they were there (and most people don't). What we are interested in finding out is whether this is learning is different in musicians and non-musicians. At the end of the music task we asked you to guess what the last syllable would be. This isn't as odd as it might have sounded at the time, because you had actually heard all the sequences before. We expected that if you noticed the sequence, you would 'guess' more right answers than if you didn't. Likewise, did you notice that some of the words that you completed in the last task could be words you had read in the list at the start of the experiment? We couldn't tell you this at the time in case you deliberately tried to memorise them and it is important that we got a test of your implicit memory (things you learn 'just by doing', not because you learned intentionally). We apologise for not giving you all of this information at the start but you can see why it was important, as we are interested in what people learn when they're not trying. For this reason, it's important that you are happy now for me to use your data. If you are not, you must tell me, and I will make sure I do not include it.

Please remember that because all data is anonymous you will not be able to withdraw from the study once you have left the testing venue.

If you have felt any discomfort or distress as a consequence of this study, please do not hesitate to seek advice from the number below

•Age UK advice – 0800 169 6565- website- www.ageuk.org.uk

If you have any questions regarding the study, please contact;
Lisa Thorpe – l.thorpe@chester.ac.uk

Dr Margaret Cousins- m.cousins@chester.ac.uk 01244 511686

Professor Ros Bramwell- r.bramwell@chester.ac.uk 01244 511477

Once again, thank you for taking part in my research.

Lisa Thorpe

Appendix 21: Participant consent form for study 3 and 4 (Chapter 6 and 7)

Consent Form

Project Title: Benefits of musical training in older adults

Investigator: *Lisa Thorpe*

Please indicate your agreement by ticking the following boxes after each of the statements and sign where indicated below:

1. I confirm that I have read and understood the information sheet for the above study and understand what is expected of me. ☐

2. I understand that my participation is completely voluntary. ☐

3. I understand that I am free to stop the study at any time and I am free to withdraw my data before leaving the testing venue. ☐

4. I confirm that I have been given the opportunity to ask questions regarding the study, and if asked, the questions were answered to my full satisfaction. ☐

Data Protection Act

I understand that data collected from me during this study will be stored on computer and that any computer files containing information about me will be made anonymous. I also understand that this consent form will be stored separately in a secure location from any data that I provide.

I agree to the University of Chester recording and processing my data and that these data will be used for a PhD thesis, and may be presented in other academic forums (e.g., academic journals, at conferences, or in teaching). I understand that my data will be used only for these purposes and my consent is conditional upon the University complying with its duties and obligations under the Data Protection Act.

Your name (print) …………………………………

Your signature ………………………………… Date ………………..

Thank you for this information. Please do not hesitate to contact us if you have any questions.

Appendix 22: Demographic questionnaire for older adults (Chapter 6)

Demographic information

Questionnaire

Participant number: _______________

Age: _____________

Gender:

Male ☐ Female ☐ Other ☐

Education:

Please state your highest qualification

No schooling qualification ☐ CSE/O Level ☐ A Level ☐ Bachelor's Degree ☐

Master's Degree ☐ Professional/Doctorate Degree ☐ Other ☐

If 'other please state ____

Do you play a musical instrument? Yes ☐ No ☐

If 'yes' please specify the total number of years playing and your primary instrument

Years ______________________

Primary instrument _________________________

Do you take part in leisure activities? Yes ☐ No ☐

If 'yes' please specify the activity you partake in ___________________

On average, how many hours per week do you assign to the above activity?

____

Appendix 23: Ethical approval for study 4 (Chapter 7)

University of Chester

UNIVERSITY OF CHESTER, DEPARTMENT OF PSYCHOLOGY
APPLICATION FOR ETHICAL APPROVAL AMENDMENT FORM

LTMC1LO119

A) Applicant and personnel

Applicant: *Lisa Thorpe*
Project title: Benefits of musical training on Implicit memory in older adults.
Applicant status: ☐ Staff → Go to Section B ☒PGR ☐Undergraduate ☐Postgraduate taught
Supervisor: *Margaret Cousins*

B) Declaration

1. ☒ I have submitted an application for ethical approval to the Department of Psychology Ethics Committee and I am required to make the following amendments to my application.
   List the recommendations of the committee.
   1) Contingency details
   2) Split the debrief into smaller sections so it doesn't look too text heavy.
   3) Include a lone working policy for recruitment testing off campus.
   Describe how you have addressed these requirements.

1) Please see appendix A for the contingency plan. This is also included in questions 10 and 11 of the original ethics application.
2) Please see appendix B for the amended debrief.
3) Please refer to Appendix C for the lone working policy.

2. ☐ I have submitted an application for ethical approval to the Department of Psychology Ethics Committee that was approved on Click here to enter a date.
   I wish the committee to consider the following amendments I would like to make to the research plan (attach the original approved application form) Click here to enter text.

☐ I am a member of staff. Signed: ____________ Date: Click here to enter a date.
Print the amendment form on BLUE PAPER and submit to the Dept. Office
☒ I am an UG/PGT/PGR student. I have discussed any amendments with my project supervisor.
Print the amendment form on BLUE PAPER and submit to the Dept. Office

Signed: ____________ (Lead Applicant) Date: 10/01/2019

Supervisor comments:
I have discussed the recommendations of the committee with the applicant and I am satisfied they have met the stated requirements./I support the amendments to the research plan. (delete as appropriate)
☐ Yes Sign and date the form ☐ No Comments: Click here to enter text.

Signed: ____________ (Supervisor) Date: 14/01/19

COMMITTEE COMMENTS:

☑ ACCEPTABLE: You may now commence with data collection subject to approval from any relevant external agencies.

DATA COLLECTION IS NOT PERMISSABLE UNDER THESE CONDITIONS

☐ ACCEPTABLE SUBJECT TO SUBMISSION OF FURTHER AMENDMENT FORM.

- ☐ Acceptable subject to conditions listed by chair. Discuss conditions highlighted with supervisor and submit ethics application amendment form direct to office.
- ☐ Acceptable subject to conditions listed by chair: Submit ethics application amendment form direct to office.

Signed: ________________ Date: 14/1/19

Appendix 24: Information sheet for individuals with dementia (Chapter 7)

Information Sheet

Project title: Differences between musicians and non-musicians with dementia

Investigator: *Lisa Thorpe, post-graduate student at the University of Chester*

Invitation to participate

You are invited to take part in a study looking at the benefits of musical training on later life. Taking part is voluntary therefore it is up to you to decide whether or not to take part. It is important for you to understand what the research is about and what it will involve. If you have any hearing difficulties that is not fixed by hearing aids, please let me know before the tasks begin. Please take time to read the following information carefully; there will also be an opportunity to discuss all information if you have any questions.

What is the project about?

The aim of this study is to look at differences between musicians and non-musicians on three different kinds of tasks. You do not have to be musical to be able to do the tasks, even though I am very interested in the differences between musicians and non-musicians. This study forms part of my PhD.

What will I be asked to do?

I would like you to fill in some information about yourself. You will then take part in some tasks

<u>Reading task</u>

- You will be asked to read a list of words that appear on the screen. There will be 50 words in total.
- Each word will appear on the computer screen. Once the participant has read the word, I will change the screen so the next word appears.

<u>Music task:</u>

- You will be asked to listen to a sequence of seven sung chords where each chord is sung on a different syllable. You'll have to decide as quickly and as accurately as possible whether the final chord is sung on the syllable dee or doo.

- There are six little sections each consisting of 8 chords.

- You can stop the task at any time.

Reaction time task

- You will see four squares on the screen. A star will appear inside one of the squares. Each square has a corresponding button on the keyboard.

- Press the right button as accurately and quickly as you can to show where the star is.

- There are 6 sections in total each consisting of 80 stars.

Altogether these perception tasks will take approximately 45mins. None of these tests will be used to diagnose any medical or psychological condition.

What are the advantages and disadvantages of taking part?

By taking part you will be adding to our understanding of the benefits of musical training, and in particular whether it has any benefits for adults diagnosed with dementia.

Taking part in this study should not cause any discomfort or distress. However, if negative feelings do arise as a consequence of taking part, you can seek advice or support from the numbers below

Age UK advice – 0800 169 6565- website- www.ageuk.org.uk
Alzheimer's society – 0300 222 1122 website www.alzheimers.org.uk

How will my information be used?

The information collected during this study will be used to produce a research article that will be used as part of my PhD thesis. The information may be published in academic journals, presented at academic conferences, or used for teaching purposes and therefore data will be stored securely for up to five years. Although the information may be used for these purposes, no-one reading the article will be able to identify that you took part or how you did in the tests because we will be looking primarily at how the different groups did. If we do look at individual data, everything will be anonymised so no-one reading can know whose it is.

Will my information be confidential?

All the information you provide will be treated in confidence. This means that your name will not be passed on to anyone else and your information will be used solely for the research or teaching purposes of the university. All their information will be stored securely and only my project supervisors and I will have access to each person's individual information.

Can I change my mind?

Yes, you can stop taking part in the study at any time and if there is any particular test you don't wish to do, or question you don't want to answer, that's fine. The tests will be as we are going through, so you know what to expect. You can also ask for part or all of your data to be destroyed before leaving the testing venue. Once you have left the room I will not be able to remove your data because it will be anonymous and I will not know whose is whose.

Who can I contact for further information?

Lisa Thorpe – l.thorpe@chester.ac.uk

Supervisors

Dr Margaret Cousins- m.cousins@chester.ac.uk 01244 511686

Professor Ros Bramwell- r.bramwell@chester.ac.uk 01244 511477

What happens next?

Please think carefully about whether or not you wish to take part in the study. If you do wish to take part, please complete the attached consent form.

Thank you for considering participating.

Appendix 25: Participant debrief for study 4 (Chapter 7)

Debrief

Project Title: Implicit learning in musicians and non-musicians diagnosed with dementia.

Thank you for helping with my study.

Previous research has established that young adult musicians and non-musicians performed equally well on tasks that involve understanding how music ‘works’ even without formal musical training. When we listen to a lot of music we learn lots about it, like learning English grammar even if we don’t know much about what verbs and nouns are. However, research also suggests that musicians are better at some other kinds of tasks, perhaps because their brains develop differently to other people’s. Psychologists call the kind of knowledge we gain without even realising it ‘implicit memory’.

There’s currently no research that looks at the benefits of music training on implicit memory of older adults diagnosed with dementia.

The study you have taken part in used 3 implicit memory tasks:

- The phoneme monitoring task
- The Serial Reaction Time Task
- A word fragment completion task.

In the phoneme monitoring task and the serial reaction time task there were sequences that you encountered that were repeated later on in the test. We expect that participants will show improvements in reaction time as their ears and eyes got used to the sequences, even if you didn’t notice they were there (and most people don’t). What we are interested in finding out is whether this is learning is different in musicians and non-musicians.

Did you notice that some of the words that you completed in the last task could be words you had read in the list at the start of the experiment? We couldn’t tell you this at the time in case you deliberately tried to memorise them, and it is important that we got a test of your implicit memory (things you learn ‘just by doing’, not because you learned intentionally).

We apologise for not giving you all of this information at the start, but you can see why it was important, as we are interested in what people learn when they’re not trying. For this reason, it’s important that you are happy now for me to use your data. If you are not, you must tell me, and I will make sure I do not include it.

Please remember that because all data is anonymous I won’t be able to take it out later.

If you have felt any discomfort or distress as a consequence of this study, please do not hesitate to seek advice from the number below.

- Age UK advice – 0800 169 6565- website- www.ageuk.org.uk
- Alzheimer's society – 0300 222 1122 website- www.alzheimers.org.uk

If you have any questions regarding the study, please contact;

Lisa Thorpe – l.thorpe@chester.ac.uk

Dr Margaret Cousins- m.cousins@chester.ac.uk 01244 511686

Professor Ros Bramwell- r.bramwell@chester.ac.uk 01244 511477

Once again, thank you for taking part in my research.

Lisa Thorpe

Appendix 26: Demographic questionnaire for individuals with dementia (Chapter 7)

Demographic information

Questionnaire

Participant number: _______________

Age: _____________

Gender:

Male ☐ Female ☐ Other ☐

Dementia diagnosis:

Yes ☐ No ☐

If 'yes' please state diagnosis____

<u>Education:</u>

Please state your highest qualification

No schooling qualification ☐ CSE/O Level ☐ A Level ☐ Bachelor's Degree ☐

Master's Degree ☐ Professional/Doctorate Degree ☐ Other ☐

If 'other' please state

____

Do you play a musical instrument? Yes ☐ No ☐

If 'yes' please specify the total number of years playing and your primary instrument

Years ____________________

Primary instrument _______________________

Do you still participate in music activity? Yes ☐ No ☐

If 'yes' please specify the activity?

____

Appendix 27: Lone working policy for data collection of study 4 (Chapter 7)

Lone working policy

As data collection will take place away from the university and in the event that it will occur at the participants home, the below policy has been agreed by the university of Chester to make sure that my safety is paramount.

1. A phone call will be made to the University of Chester, Psychology office, informing them of my arrival at the data collection destination.
2. 10 minutes after arrival, a phone call will be made by myself to the University inform them that I am safe, and all is fine or that the situation isn't ok, and the participant is acting in an unsafe manner. If the participant is acting hostile or in a violent manner a code word would be used "Can you please tell Margaret, I will be 10 mins late"
3. A follow up phone call will by made by the office to my phone to check up on events. If the issue has not been resolved, it would be at this point that I would leave the data collection and the destination by informing the participant that "there is a problem and I need to go back to the office"

All data collection will be completed during office hours to ensure that this protocol can be followed throughout data collection.